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EDITORIAL

THE COCONUT INDUSTRY

ATTENTION may be directed to the report of the Empire Marketing Board which is published in the present number of *The Tropical Agriculturist.* It is of interest to coconut planters and those who handle coconut products. The report was made at the instance of the government of Fiji, a fact which shows that the depression of the coconut industry is affecting other countries than Ceylon, and we are indebted for a copy of it to the Agricultural Adviser to the Secretary of State for the Colonies. A copy of the report has been placed in the hands of the Chairman of the Commission which is considering the state of the local coconut industry with a view to reporting on the steps to be taken to assist it.

The figures for 1929 show that in the case of fresh coconuts and copra an increase of exports from Ceylon was accompanied by a decrease in the value of the products. Desiccated coconut exports compare unfavourably with those of 1928 in both amount and value, while the figures for coconut oil and poonac show increases over 1928 in both quantities exported and their values. The price of copra fell in 1926, recovered to a slight extent in 1927 and fell again in 1928. The fall was continued in 1929 although there was a recovery in June. The copra market was affected by the large and cheap supplies of grain which were available and by the consequent fall in demand for oil-cake for the feeding of cattle. It will be noted that present-day copra production is almost double that of pre-war years. The high prices obtained by growers during the years immediately following the war led to an extension of coconut planting which is responsible for the present over-production. Further, new areas have yet to come into bearing, and it follows that a remedy for the present position lies in an increase in the demand for copra through the finding of new markets and new uses for it and through the cheapening of production.

There is also the question of competing products. The production of whale oil, groundnuts and vegetable oils in general has increased, and soya beans have been used by the makers of margarine in increasing quantities. The soya bean is exported from China and Korea, and, whereas the exports of China averaged 685,000 tons over the years 1909-1913, they rose to 1,732,000 tons in 1927. The soya bean is therefore a serious competitor in the vegetable oil market. It is pointed out in the report, however, that copra is in greater demand by the makers of margarine than are oil seeds. Copra prices may be affected by the buying policy of the margarine combine which was established in 1929 for, when supplies are large, the combined buyers may be able to depress the market. The remedy would seem to lie in co-operative marketing by the sellers.

The above points must be considered, but the importance of cheaper production must not be overlooked. Coconut cultivation is capable of an all-round improvement through the adoption of manuring and green-manuring programmes and of methods for the conservation of soil moisture, and the progressive policy of removing low-yielding palms and replacing them with plants derived from selected high-yielding palms may be urged on the industry. Attention should also be given to the processes of manufacture; a reliable product is always in greater demand than a variable product. It is apparent that interesting and profitable lines of work await the attention of the Coconut Research Scheme and it is hoped that the Scheme will play in due course a large part in the improvement of the coconut industry.

A FURTHER NOTE ON *INDIGOFERA ENDECAPHYLLA* AS A COVER CROP FOR TEA

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INTRODUCTORY

IN an article entitled "Tea and *Indigofera endecaphylla*" published in *The Tropical Agriculturist* of February, 1928, the writer reviewed the ascertained and probable results of planting such a cover crop in tea. The yields of another two-year period are now available from the Peradeniya plots, and, in addition, the replies to the questionnaire on green manuring sent to all estates in December, 1928, have furnished a certain amount of information on estate experience and practice with this cover.

The advantages and possible disadvantages of a cover crop in tea are now generally known but may be briefly recapitulated.

Advantages:

(1) Prevention or lessening of soil erosion.

(2) Addition of organic matter to the soil, resulting in an added capacity to retain moisture and improved physical condition.

(3) Opening up and improvement of the physical condition of the soil by the root action of the cover crop.

(4) Increase of nitrogen if a leguminous crop is used.

(5) The shading of the ground.

The ultimate criterion of the value of a cover crop must of course rest on whether larger crops per acre are obtained and whether the value of such increase in crop is greater than the additional expenditure incurred.

Possible Disadvantages:

(1) The cover crop may creep up and smother the tea bushes.

(2) Snakes and leeches.

(3) The cover crop may by undue absorption and transpiration of moisture detrimentally affect the tea.

(4) The control and treatment of the cover crop may prove too expensive or absorb more labour than the estate can spare.

With regard to (1), *Indigofera endecaphylla* will not climb up a bush; it will grow up through a bush but is quite easily removed by hand.

The presence of snakes is perhaps the most serious objection to a cover crop in tea. Two pluckers have been bitten in four years at Peradeniya. As a general rule leeches do not seem to be very troublesome in *Indigofera* but after the heavy rains in November, 1929, a good many were found at Peradeniya.

The fear of undue loss of moisture does not seem to have materialised. The Agricultural Chemist has found that after the cover has been in possession of the ground for two years or so less moisture is lost from soils under a cover crop than from bare soils. Probably the effective check to the run-off and consequent increased entry of rain into the soil is a potent factor in retaining moisture. Tea at Peradeniya does not appear to have suffered at all in this respect.

With regard to the labour question it is hard to estimate actual increases and savings of expenditure due to the presence of a cover crop. The headings may be tabulated as under.

Savings in expenditure		Increases in expenditure
Weeding	...	Planting cover crop
Drains	...	Manuring or forking

Weeding will cost more in the early stages of growth of the cover but there will certainly be an eventual saving. When the cover is fully established drains can be neglected. Drains on the *Indigofera* plots at Peradeniya have not required attention for three years. The increased cost of manuring or forking depends partly on the cultural treatment of the cover plants to be undertaken, and this question will be discussed later.

THE PERADENIYA EXPERIMENT

After pruning in October-November, 1925, fourteen plots comprising six half-acre plots and two one-acre plots of old tea which had previously been used for a manurial experiment were planted with *Indigofera endecaphylla*. These plots were previously under a manurial experiment and the same manurial treatment has been continued throughout. To apply the manures the method has been to make a vertical cut down the middle of the row with a grass knife and drag back the creeper to both sides of the row to be manured with mamoty forks. The manures are then broadcasted down the middle of the row and forked in by envelope-forking. After the first manuring the roll of *Indigofera* was laid back again but this extra labour was subsequently considered unnecessary. In later applications no further action was taken and a fresh cover was rapidly formed from the roots left in the ground when the creeper

was rolled back and from growth from the sides. The operation of cutting and rolling back the creeper is done by a gang of one man and two women and, for alternate rows, costs about Rs. 5.00 per acre.

All other operations such as plucking and pruning have been continued in exactly the same manner as formerly, so that, except for the presence of the *Indigofera*, conditions have remained the same. No forking in or other cultural treatment of the *Indigofera* has been attempted, the object being in the first instance to ascertain the effect of the mere presence of the cover crop on the yield and health of tea.

In considering yields of green leaf the period between two prunings is taken as the crop period, and the period between the 1923 and the 1925 prunings, when no *Indigofera* was present, is taken as the standard of comparison.

In the previous article in addition to the actual yields the calculated yields for a full acre of 2722 bushes of a half acre of 1361 bushes were taken into consideration. The object of such a calculation was to allow for differences in the number of bushes in bearing in different periods due to deaths after pruning and to supplies coming into bearing.

Such a calculation is now considered unsound. In this instance this form of calculation results in a most irregular set of figures and these are not published. The number of bushes in bearing (from a census taken in the middle of each period) is however given.

As the manures applied may have some interaction on the effect produced by the *Indigofera* this information is also given.

Percentage increase or decrease in actual yields of green leaf over 1923-25. Pruning, together with bushes in bearing and manures applied.

Plot	Acreage	Bushes in bearing 1923-25	Percentage increase or decrease of 1925-27 over 1923-25 with *Indigofera*	Bushes in bearing 1925-27	Percentage increase or decrease of 1927-29 over 1923-25 with *Indigofera*	Bushes in bearing 1927-29	Manures applied annually in April Pounds per acre	
141 A	½	938	—9	1028	+4	891	Ground nut cake ... Sulphate of potash ...	286 50
141 B	½	946	—8	1051	+2½	966	Ground nut cake ...	286
142 A	½	942	+½	961	+10	941	Ground nut cake ... Superphosphate ...	286 111
142 B	½	1055	—1	1148	+5	914	Ground nut cake ...	286
143 A	½	876	—½	758	+5	696	Superphosphate ... Sulphate of potash ...	111 50
143 B	½	778	—2	676	—4½	674	Ground nut cake ... Superphosphate ... Sulphate of potash ...	286 111 50
145	1	2286	—10	2036	—7	1918	Control ...	—
146 A	½	1171	—3	1186	+4	1106	Ground nut cake ... Sulphate of potash ...	286 50
146 B	½	1134	—½	917	+3	1102	Ground nut cake ...	286
147 A	½	954	—3	1056	+5	1056	Ground nut cake ... Superphosphate ...	286 111
147 B	½	1018	+6	917	+9	1119	Ground nut cake ...	286
148 A	½	877	+8	900	+20½	1005	Ground nut cake ... Superphosphate ... Sulphate of potash ...	286 111 50
148 B	½	999	+4	1062	+19	1130	Ground nut cake ... Superphosphate ... Sulphate of potash ...	286 111 50
149	1	2276	+5	2270	+4	2186	Dadaps only ...	—
Total		16250	—1	14956	+4½	15704		
Rainfall in inches for crop period ...		1923-25 198·77		1925-27 186.46		1927-29 169·33		

In addition to the above manures all plots receive 100 lb. of basic slag and 60 lb. of sulphate of potash per acre after pruning

The table shows a nett decrease in yield of 1 per cent. in the first two-year period and a nett increase of $4\frac{1}{2}$ per cent. in the second period. In the 1925-27 period the effect of the *Indigofera* would scarcely be fully felt and in addition there were 1294 less bushes in bearing and the rainfall was 12.31 inches less than in the 1923-25 period.

In 1929 the pruning was started a month earlier than usual and the cropping period was thus a month shorter than the other two periods. There were, it is true, 748 more bushes in bearing, but against this the rainfall was no less than 29.44 inches less than that of 1923-25 and 17.13 inches less than that of 1925-27. In spite of these disadvantages all the plots except two have in the last period shown substantial increases in yield. There are no proper controls in this experiment but it may be mentioned that plots 144, 150 and 155, parts of which were under another manurial experiment, showed *decreases* in yield of between 24 per cent. and 40 per cent. in the 1927-29 period compared with the 1923-25 period.

1929 was a particularly dry year and if any ill-effect was to have been observed as the result of undue absorption of moisture by the cover crop one would have expected to observe it in that year. The tea however remained vigorous and looked better than clean-weeded tea.

SOIL ANALYSIS

Soil analyses were made in the Chemical Laboratory at the end of each two-year period. The results will be only generally mentioned as they will be more fully discussed by the Agricultural Chemist in a separate article.

At the end of the 1925-27 period there was a distinct increase of over .01 per cent. of nitrogen in five plots and a distinct fall in four plots. On the whole there was a slight decrease in nitrogen. At the end of the 1927-29 period, however, there was a substantial increase of nitrogen content in nearly all plots.

There was a satisfactory increase in organic matter at the end of the 1925-27 period and a further considerable increase at the end of the 1927-29 period.

Mechanical analyses were also made and showed that in the 1925-27 period there was a loss of silt and clay (presumably due to erosion) in spite of the presence of *Indigofera*. This loss however now appears to have been checked as at the end of the 1927-29 period no further decrease of silt and clay was found to have occurred.

CULTURAL TREATMENT

Although, as stated, no cultural treatment, other than the clearing of the cover crop necessary for the application of

manures, has been attempted at Peradeniya, information from estates shows that such treatment is being undertaken in a number of cases.

Some estates cut and fork in the creeper; others fork it in without cutting. Costs of cutting and forking in the creeper varying between Rs. 4.80 and Rs. 5/- per acre are given. One estate cuts the creeper at manuring, throws it into the next row and forks it in at a total cost of Rs. 7.50 per acre. There is no difficulty about forking through the creeper without cutting it but the writer's experience is that it is difficult to incorporate any considerable amount of green material in the soil without cutting first.

There is little doubt that forking in the creeper will bring increased benefit but it must also be pointed out that the mere presence of the creeper has at Peradeniya undoubtedly improved the physical condition of the soil.

NEW CLEARINGS

The planting of a cover crop in new clearings is a vexed question. The greatest loss of surface soil is likely to occur in the first year or two after clearing and therefore to delay the planting of a cover crop would be equivalent to shutting the stable door after the horse had gone. It is sometimes maintained however, that *Indigofera* strangles young tea plants and should not be planted in the first year or two. A Badulla estate complains that the creeper absorbs too much moisture in the dry weather and that the young tea plants have suffered accordingly. Another estate in the same district says that *Indigofera* has been found definitely injurious to young tea. An estate in the Kelani Valley says that the creeper strangles young tea plants. On the other hand a Moneragalla estate (another dry district) says that it has proved a great success in young clearings. The writer's experience at Peradeniya is that supplies definitely come on better among *Indigofera* than in clean-weeded areas but that after centering plants do not spread so well. It would appear probable that in new clearings the moisture factor assumes predominance and in the drier districts the planting of *Indigofera* may not be advisable in new clearings for the first year or two. In the wetter districts planting may be recommended as long as the young tea plants are kept sufficiently clear of the creeper.

A NOTE ON THE EFFECT OF *INDIGOFERA ENDECAPHYLLA* ON THE NITROGEN AND ORGANIC MATTER CONTENTS AND THE MECHANICAL CONSTITUTION OF TEA SOILS AT PERADENIYA

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IN a paper entitled "A Further Note on *Indigofera endecaphylla* as a Cover Crop for Tea" in this issue of *The Tropical Agriculturist*, Mr. T. H. Holland, Manager of the Experiment Station, Peradeniya, gives an account of the experiment begun in 1925 to determine the effects of a cover of *Indigofera* on tea. He indicates that, from the point of view of crop yield, the cover has produced beneficial results during the second period of its growth, *i.e.*, from 1927 to 1929. In order to ascertain whether the cover was producing equally beneficial effects on the soil and whether it was effectively preventing soil erosion, nitrogen and organic matter determinations and mechanical analyses of soil samples taken from the plots were made in the Chemical Laboratory in October-November 1925, 1927 and 1929 respectively. The soil samples were taken to a depth of 9 inches, in every case before pruning, and in 1925 just before the cover was planted. There were altogether sixteen soil samples examined at each sampling though the yield data from only fourteen of the plots were dealt with by Mr. Holland. The analytical determinations were carried out on air-dry soil sieved through a 3 mm. sieve, as in the old British method of analysis, the reason being that when the analyses were started in 1925 the new method had not become official. Nitrogen was determined by the Kjeldahl method and for the purpose of this investigation loss on ignition was taken as organic matter. This is not strictly correct, but, as the results are comparative, it answers the purpose satisfactorily.

The results are shown in tables I., II., III., and IV. below. Tables I and II show the results of mechanical analyses of the soils and table III the results of the chemical analyses. The detailed figures of the mechanical analyses are not given, but only the percentages of fine and coarse soil particles. Table IV shows the average percentages of nitrogen, organic matter, coarse soil and fine soil for the years 1925, 1927 and 1929.

Table I

Per cent fine gravel + coarse sand + fine sand

Year	PLOT															
	141A	141B	142A	142B	143A	143B	145	146A	146B	147A	147B	148A	148B	149	163	164
1925	70·37	67·50	74·65	71·28	71·09	65·89	68·11	67·00	70·48	70·75	77·55	73·85	70·48	—	63·12	60·71
1927	69·45	71·89	74·40	75·27	67·57	61·26	70·47	77·41	74·28	73·21	76·20	80·40	78·24	73·54	61·75	64·66
1929	65·31	72·72	73·24	70·07	65·31	72·25	74·45	73·68	74·34	72·74	70·22	77·77	71·38	72·63	69·82	68·52

Table II

Per cent silt + fine silt + clay

Year	PLOT															
	141A	141B	142A	142B	143A	143B	145	146A	146B	147A	147B	148A	148B	149	163	164
1925	21·55	25·99	18·95	22·09	23·64	26·81	26·45	26·02	22·65	22·93	16·63	20·05	24·59	—	27·69	30·94
1927	22·71	20·52	19·82	18·18	24·27	29·48	23·09	18·04	20·89	21·08	19·04	14·53	15·51	19·39	20·29	25·36
1929	26·80	19·93	19·36	22·39	27·87	20·20	18·35	18·28	18·66	20·08	21·35	15·62	21·98	19·36	21·98	23·50

From tables I and II it will be noted that the soils are light sandy loams. The 1927 and 1929 soil samples are, on the whole, much the same in mechanical composition, but the 1925 samples have slightly higher percentages of finer particles. This would appear to indicate that though, on the average, a small proportion of the finer soil particles appears to have been washed away up to 1927 in spite of the *Indigofera*, further losses of these soil particles have since been checked, presumably owing to the improved growth of the cover.

Table III

Per cent nitrogen

Year	PLOT															
	141A	141B	142A	142B	143A	143B	145	146A	146B	147A	147B	148A	148B	149	163	164
1925	·066	085	·092	·068	·058	·100	·169	·104	·096	·108	·091	·083	·084	—	·117	·095
1927	·090	·084	·110	·080	·077	·105	·082	·072	·092	·080	·071	·077	·096	·093	·112	·079
1929	·099	·104	·103	·111	·091	·091	·101	·097	·092	·103	·092	·082	·106	·112	·094	·092
	Per cent organic matter															
1925	5·69	3·78	4·15	4·41	3·52	5·14	2·85	4·63	4·43	3·68	3·69	3·95	3·89	—	5·60	4·98
1927	5·12	4·64	4·45	4·15	5·42	6·25	4·21	3·28	3·44	3·66	2·99	3·68	4·68	4·87	5·69	6·48
1929	5·58	5·37	5·17	5·38	4·81	5·29	5·14	5·67	4·96	5·04	6·13	4·63	3·66	5·52	5·72	5·67

Table IV

		1925	1927	1929
Average nitrogen	per cent	·096 (·089)	·087 (·088)	·098
,, organic matter	,,	3·73	4·56	5·29
,, silt + clay	,,	23·8	20·8	20·9
,, gravel + sand	,,	69·5	71·8	71·5

An examination of tables III and IV will show that there is in most cases an increase in the nitrogen contents of the soil samples in 1929 over those of 1927. The average percentage for all samples is ·098 in 1929 as compared with ·087 in 1927 and ·096 in 1925. The high 1925 average is due to the unaccountably high nitrogen content of the sample from plot 145 in that year. If the results of this plot are eliminated, the average nitrogen percentages work out at ·089 in 1925 and ·088 in 1927. These figures are bracketed in table IV. It will thus be seen that partly as a result of the growth of the cover and perhaps partly owing to the yearly application of a nitrogenous manure mixture to most of the plots, the nitrogen contents of the plots appear, on the whole, to be steadily increasing even though the cover is not ploughed in. The addition of the 20 lb. of nitrogen per acre to some of the plots has probably had some effect on the soil nitrogen contents of the latter, either directly or indirectly, but, as four of the plots that had no nitrogenous manures added to them have also shown increases in nitrogen, it is reasonable to infer that the leguminous cover crop has certainly contributed towards the increase in soil nitrogen.

As regards organic matter gauged by loss on ignition, the table shows clearly that there is a steady and appreciable increase in the organic matter contents of all the plots as a result of the growth of the cover. In 1925 the average organic matter content was 3·73 per cent., in 1927 it was 4·56 per cent., and in 1929 as much as 5·29 per cent. The percentage increase of the 1929 organic matter average over that of the 1925 average is over 40. The organic matter increase is due to decomposed *Indigofera* material.

SUMMARY

The analytical examination of soil samples from the tea plots at the Experiment Station, Peradeniya, under *Indigofera endecaphylla* carried out in 1925 before the cover was planted and again in 1927 and 1929 respectively show that (1) though there appear to have been losses of some of the finer soil particles through erosion between 1925 and 1927 when the cover was being formed, the losses have been effectively checked since, apparently as a result of the improved growth of the cover ; (2) there is a fairly appreciable increase in the average nitrogen content of the plots in 1929 over that of 1927; the 1927 average is the same as that of 1925 if the unexpectedly high result of one plot is left out in the calculation of this average; (3) there has been a large and steady increase in the organic matter (loss on ignition) contents of all the plots since 1925, the 1929 average being as much as 40 per cent. higher than that of the 1925 average.

CHEMICAL NOTES (8)

THE MANURIAL AND FEEDING VALUE OF A BY-PRODUCT OF THE COCONUT OIL INDUSTRY

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A sample of cake reported to have been obtained as a by-product of the coconut oil industry was recently sent for investigation of its feeding and manurial value. As the results of the analysis are of general interest they are published in the hope that this by-product of the coconut will find some use. The table below shows the analysis of the sample of cake and its feeding and manurial value. The analyses of samples of coconut poonac and of linseed cake are shown for purposes of comparison.

FEEDING VALUE

	Coconut oil residue cake per cent	Coconut poonac per cent	Linseed cake per cent
Moisture	10·17	7·56	11·0
Proteins	30·69	21·50	32·3
Ether extract (fat)	16·44	10·02	9·9
Carbohydrates	35·13	42·23	32·2
Fibre	0·93	11·85	8·7
Ash	6·64	6·84	5·9
	100·00	100·00	100·0
Food unit	152·9	121·0	137·7
Nutritive ratio	1:2·4	1:3	1:2

MANURIAL VALUE

	per cent	per cent
Nitrogen	4·91	3·33
Phosphoric acid	2·13	1·47
Potash	1·80	1·29
Lime	1·09	0·90

It will be noted that as regards feeding value the cake appears superior to coconut poonac and even to linseed cake which it closely resembles in appearance. Its fat and protein contents are much higher than those of coconut poonac while its fibre content is extremely small when compared with that of any other cake. It contains more food units than either coconut poonac or linseed cake, and has a nutritive ratio which is between

that of coconut poonac and of linseed cake. The cake should therefore be useful as a concentrated feeding stuff for cattle and pigs. The sample examined had however a rancid odour and if all samples of the cake are similar in this respect, it will not be suitable for cattle, especially dairy cattle, except perhaps in very small quantities and unless mixed with other feeding stuffs. It is however worth experimenting with on a small scale.

As regards its manurial value the analysis indicates that it is richer in nitrogen, phosphoric and potash than either coconut poonac or castor cake. It is therefore a valuable organic manure but for its high fat content which will render its decomposition in the soil very slow. If, however, some of the fat it contains is expressed by means of solvents or other means, the residual cake will be an excellent organic manure. As the cake is reported to be obtainable from local oil mills at about Rs. 50.00 per ton as compared with castor cake at Rs. 110.00 per ton, and in fairly large quantities, it will be realised what a useful source of feeding and fertilising material coconut oil residue cake may be.

ANALYSIS OF *TRIDAX PROCUMBENS* ("KURUNEGALA DAISY")

A sample of the weed *Tridax procumbens* which grows profusely in the Kurunegala district where it is popularly known as the Kurunegala daisy was forwarded for analysis. As the results of the analysis are interesting they are published for general information.

	On fresh material	On material at 100°C.
	per cent	per cent
Moisture	86·90	—
*Organic matter	9·70	74·03
+ Ash	3·40	25·97
	100·00	100·00
*Containing nitrogen	·332	2·53
+ Containing		
potash	·835	6·37
lime	·449	3·43
phosphoric acid	·154	1·17

It will be noted that this weed contains comparatively large quantities of potash, phosphoric acid and lime, especially of the two former. The nitrogen content is comparatively low. It should therefore be weeded out from land under annual crops. If it grows under coconuts, it should be periodically cut before the flowering stage and left as a mulch on the surface or used as a green manure.

THE COCONUT INDUSTRY

[The following report was submitted to the Government of Fiji by the Empire Marketing Board. We are indebted to the Agricultural Adviser to the Secretary of State for the Colonies for a copy of it.—Ed., *T.A.*]

Average prices per ton of Federated Malay States Singapore copra c.i.f. London, during recent years have been as follows:

Table I

Annual average prices of copra

Year	Price per ton £.	s.	d.	Year	Price per ton £.	s.	d.
1916	33	13	9	1923	27	17	6
1918 (controlled)	45	10	0	1924	29	15	0
1919	52	10	0	1925	30	5	0
1920	56	7	6	1926	28	12	6
1921	30	12	6	1927	27	10	0
1922	24	15	0	1928	26	17	6

2. Changes in quotations for copra during the past three years are shown below:

Table II

Variations in copra prices 1926-1928

	£	s.	d.		£	s.	d.		£	s.	d.
1926 January	29	7	6	December	26	2	6	*Fall*	3	5	0
1927 ,,	27	2	6	,,	28	7	6	*Rise*	1	5	0
1928 ,,	28	12	6	,,	25	0	0	*Fall*	3	12	6

During the current year the price fell to £20.10.0d. in May but rose in the following month to £24.10.0d. again receding to £23 in August. The low prices early this year are partly attributable to prospects of plentiful supplies of grain, offering a cheap feeding stuff for cattle as an alternative to oilcake.

3. There has of course been a very substantial increase in the production of copra in comparison with pre-war years. The following figures extracted from the Year Book of the International Institute of Agriculture (with certain later figures where available) show the average net exports of copra in the quinquennium 1909-13, and during the past five years, with separate particulars for the five groups of countries which together account for some 90 per cent. of the quantities entering world trade.

Table III

World exports of copra

	1909-13	1924	1925	1926	1927	1928
	Thousand tons			Thousand tons		
Total	545	875	907	1008	903	—
British Malaya	4	92	86	104	87	95
Dutch E. Indies	234	338	335	371	300	431
Philippines	128	154	145	171	196	234
Ceylon	41	88	113	121	99	99
South Seas	70	139	148	159	159*	—

* Provisional.

4. The high prices ruling for copra in 1919 and 1920 resulted in an increase in coconut plantations. After the slump of 1920-21 prices rose from 1922 to 1925 and it was not until 1926, when the new plantations began to come into bearing, that the increase in world supplies showed signs of outstripping the increase in demand. World supplies in 1927 fell back to about the 1925 level and it is noticeable that there was some appreciation in values during the year, but although complete figures for 1928 are not yet available, there was evidently a striking recovery in supplies in that year, four groups of countries, which together account for 75 per cent. of the world's exports, having an export 12 per cent. in excess of the 1926 total and 26 per cent. higher than in 1927. Information obtained from trade sources indicates that during the first quarter of the current year world shipments showed a further appreciable increase over the corresponding period in 1928, but that there was a decline during the second quarter. These fluctuations are reflected in the varying quotations for copra during 1929, given in paragraph 3 above.

5. It appears, therefore, that the fall in copra prices during the past 1½ years has been partly due to increased production, following the high prices, and consequent new plantings, in 1919-20. The majority of new plantations established during these two years are presumably now in bearing and although production may be expected to continue to increase for a year or two, there is every probability that the rate of increase will tend to slow down. On the other hand, there is reason to believe that the consumption of copra will continue to increase owing to the growth of population and the increasing use of vegetable oils.

6. With regard to competitive products, it is no doubt true that the increased production of groundnuts and whale oil, both of which are largely used in margarine making, has contributed to the depression in the copra market, and the increased world production of other vegetable oils is doubtless a further contributory factor. World exports of groundnuts during pre-war and recent years are given in table IV below:

Table IV

World exports of groundnuts.

	1909-13	1924	1925	1926	1927	1928
	Thousand tons		Thousand tons		Thousand tons	
Total	*555*	*992*	*1333*	*1377*	*1293*	—
British India	192	243	463	444	475	749
French W. Africa	205	312	444	480	404	386
British W. Africa	64	139	176	188	160	195
China	39	196	168	176	—	—

7. It is of course impossible to foretell with any degree of accuracy what may be the further trend in production of an annual crop such as groundnuts. Any continued depression in market values would presumably be followed in due course by a reduction in acreage under cultivation. As regards whale oil, figures of production, obtained from trade sources, indicate an increase from 109,000 tons in 1922 to 203,000 tons in 1927 and 226,000 tons in 1928. Production in 1929 is expected to reach nearly 300,000 tons.

8. It is impossible to determine to what extent recent combinations of buyers and the creation of a margarine combine covering the greater part of margarine production in this country and on the Continent have affected the market for copra. It appears, however, that since both copra and palm kernels are more exclusively used for margarine than other oil seeds, their price depends to a larger extent on the buying policy of the margarine

combine. When supplies are in excess of demand a combination of buyers may undoubtedly depress the market unduly to the disadvantage of sellers and has led in other industries to combination or co-operative selling on the part of producers.

9. As you are aware the Board's Statistics and Intelligence Branch undertakes periodical surveys of the world position of certain commodities, and the question of a world survey of the production and consumption of oil seeds is now under consideration. The above information has been compiled on the basis of information already available in the publications of the International Institute of Agriculture supplemented by trade statistics, but it is hoped that more complete figures will be obtained as a result of the world agricultural census of 1930.

Table A

Domestic exports of coconuts from producing countries in the Empire, with the corresponding figures for the Dutch East Indies and the Philippines

Exporting country	Unit	1925	1926	1927	1928
British West Indies:					
St. Vincent	No.	9,435	20,463	11,383	(a)
	£	20	102	52	(a)
St. Lucia	No.	123,516	118,501	96,813	141,667
	£	432	381	351	499
Grenada	No.	50,500	38,100	27,200	32,770
	£	111	85	58	(a)
Leeward Islands (b)	No.	229,990	300,494	538,057	(a)
	£	1,198	2,326	3,885	(a)
Jamaica	No.	26,380,697	23,040,616	33,179,198	31,104,831
	£	154,122	103,378	166,887	159,426
Trinidad & Tobago	No.	8,633,981	5,041,036	6,463,765	6,799,655
	£	45,834	25,135	32,298	34,824
Bahamas	No.	3,000	23,320	—	—
	£	14	99	—	—
British Honduras	No.	5,785,158	5,512,560	5,929,834	(a)
	£	28,298	(a)	(a)	(a)
British Guiana	No.	1,363,280	815,917	334,185	321,635
	£	7,146	3,904	1,254	1,237
Ceylon	No.	23,288,786	16,951,368	18,875,750	18,016,191
	£	146,131	104,396	113,320	106,928
British India	No.	265,029	134,230	178,359	146,305
	£	1,726	829	1,166	949
North Borneo	No.	292,653	668,693	681,208	(a)
	£	1,032	2,338	2,387	(a)
Sarawak	No.	10,411	5,883	14,034	11,285
	£	32	31	70	90

(a) Information not available.

(b) Including exports from certain Leeward Islands to other Leeward Islands (inter-presidency trade), amounting to: *1925*, 73,376, value £383; *1926*, 93,476, value £561; *1927*, 41,975, value £248.

Table A *(Contd.)*

Exporting country	Unit	1925	1926	1927	1928
Fiji	No.	243,340	153,570	386,213	(a)
	£	1,420	1,107	1,160	(a)
Federated Malay States	tons	125	80	75	87
	£	534	356	316	375
Unfederated Malay States (Kelantan)	No.	141,000	300	(a)	(a)
	£	497	1	(a)	(a)
Straits Settlements (Exports less Imports) (d)	tons	13,073	9,851	13,404	(c) 6,105
	£	53,858	45,936	66,106	(c) 29,710
Zanzibar	No.	527,066	630,090	775,036	608,034
	£	2,021	2,496	3,006	2,700
Kenya & Uganda	tons	58	91	43	22
	£	365	595	314	176
Seychelles	No.	61,000	83,900	12,500	21,500
	£	230	331	43	77
Gold Coast	No.	160	4,495	145	218
	£	1	35	1	2
Nigeria	No.	188	1,453	203	350
	£	2	7	2	3
Sierra Leone	No.	1,010	2,396	4,791	(a)
	£	7	15	36	(a)
Dutch East Indies	No.	136,304	207,039	138,838	(e) 27,467
	£	454	864	588	(e) 147
Philippine Islands	No.	6,170	10,375	1,000	1,186
	£	35	57	5	5

(a) Information not available.

(c) Figures are for six months, January to June, 1928.

(d) Domestic exports should be not less than the figure given, but may be about 10 per cent. higher if imports are retained for consumption.

(e) Java and Madura only.

Table B

Domestic exports of copra from producing countries in the Empire, with the corresponding figures for the Dutch East Indies and the Philippines

Exporting country	Unit	1925	1926	1927	1928
Ceylon	tons	113,686	120,970	99,108	98,833
	£	2,881,620	2,984,905	2,381,812	2,387,510
British India	tons	103	1,635	907	101
	£	5,113	49,154	24,395	4,694
Federated Malay States	tons	57,997	65,829	57,536	68,504
	£	1,321,011	1,497,177	1,183,389	1,337,189

Table B *(Contd.)*

Exporting Country	Unit	1925	1926	1927	1928
Unfederated Malay States (Johore, Kelantan, Trengganu, Perlis)	tons	36,680	42,158	38,355	(g) 9,105
Straits Settlements	tons	142,833	168,083	125,721	(c) 55,174
(total exports) (b)	£	3,526,937	3,920,441	2,755,285	(c) 1,267,653
Straits Settlements	tons	150,573	170,495	133,442	(c)62,438
(total imports) (b)	£	3,392,928	3,738,852	2,758,448	(c) 1,316,750
North Borneo	tons	3,788	4,833	3,222	(a)
	£	73,676	90,004	54,347	(a)
Sarawak	tons	713	1,182	1,196	1,852
	£	16,410	26,610	24,707	32,653
Territory of New Guinea	tons	39,151	45,806	47,613	(a)
	£	815,938	1,016,930	849,852	(a)
British Solomon Islands (d)	tons	16,508	19,206	22,316	21,957
	£	287,702	369,283	411,597	348,793
Papua (e)	tons	7,765	8,619	9,542	(a)
	£	172,905	204,125	186,837	(a)
Fiji	tons	24,133	27,868	26,560	(a)
	£	497,713	573,475	534,416	(a)
Tongan Islands	tons	13,758	13,992	11,252	15,671
	£	280,386	255,156	225,344	282,083
Western Samoa	tons	14,519	12,250	11,655	(a)
	£	331,274	275,086	242,672	(a)
New Hebrides	tons	7,371	8,382	10,204	(a)
(Condominium)	£	162,154	184,318	204,090	(a)
Gilbert and Ellice	tons	5,692	6,341	2,544	(a)
Islands	£	95,928	128,461	39,341	(a)
Zanzibar	tons	17,246	17,354	14,182	15,493
(Domestic exports) (f)	£	377,018	375,249	336,163	372,780
(Total exports less	tons	12,481	12,790	10,052	9,359
imports) (f)	£	275,907	281,113	241,525	235,513
Tanganyika	tons	7,623	7,348	7,267	9,318
	£	160,800	152,228	143,024	191,197
Kenya and Uganda	tons	1,565	1,101	736	1,348
	£	35,915	25,763	14,070	28,955

(a) Information not available.

(b) Total imports exceed total exports.

(c) Figures are for period January to June, 1928.

(d) Years ended 31st March of years stated.

(e) Years ended 30th June to year stated.

(f) "Domestic exports" are taken from the "Annual Trade Report of Collector of Customs." Trade statistics are also published in the Blue Book with the following note: "Owing to the practice of bulking it is considered that these figures are inaccurate, and domestic exports should be arrived at by deducting imports from total exports." This note does not appear in the "Trade Reports."

(g) Kelantan and Perlis only.

Table B *(Contd.)*

Exporting country	Unit	1925	1926	1927	1928
Seychelles	tons	4,797	5,359	4,540	4,896
	£	120,884	128,726	100,891	109,497
Mauritius	tons	854	984	1,374	1,393
	£	11,620	21,345	25,004	30,898
Gold Coast	tons	1,324	1,513	1,454	1,456
	£	30,704	33,482	30,674	32,245
Nigeria	tons	194	116	135	294
	£	3,592	3,999	2,947	6,242
British West Indies:					
St. Vincent	tons	295	340	535	672
	£	5,512	9,826	10,083	12,543
St. Lucia	tons	99	80	204	315
	£	3,563	1,808	4,409	8,690
Grenada	tons	23	68	63	119
	£	784	1,420	1,378	(a)
Leeward Islands	tons	29	56	64	(a)
	£	812	1,662	1,796	(a)
Jamaica	tons	1,567	4,403	3,607	3,415
	£	40,877	96,647	70,636	74,101
Trinidad & Tobago	tons	4,449	6,187	5,580	9,532
	£	131,243	166,263	146,895	227,555
British Guiana	tons	863	1,706	1,163	3,501
	£	20,023	39,595	24,276	73,442
British Honduras	tons	302	665	894	(a)
	£	5,954	(a)	(a)	(a)
Dutch East Indies	tons	345,466	370,930	306,151	438,267
	£	8,532,674	8,028,214	6,034,897	8,746,045
Philippine Islands	tons	144,392	171,273	196,171	230,715
(total exports) (h)	£	3,251,117	3,776,256	3,940,700	4,630,719

Table C

Domestic exports of coconut oil from producing countries in the Empire, with the corresponding figures for the Dutch East Indies and the Philippines

Exporting Country	Unit	1925	1926	1927	1928
Ceylon	Cwt.	616,917	570,463	673,153	779,112
	£	1,266,020	1,160,249	1,239,159	1,446,361
British India	Cwt.*	8,193	15,264	8,193	6,132
	£	20,751	36,709	19,637	14,992
North Borneo	Cwt.	301	362	543	(a)
	£	595	724	1,068	(a)

(a) Information not available.

(h) Imports of copra amounted to:

	Tons.	Value £
1925	—	—
1926	245	6,807
1927	129	1,938
1928	1,015	18,115

* Converted from gallons at the rate of 8·715 lb. = 1 gallon.

Table C (*Contd.*)

Exporting country	Unit	1925	1926	1927	1928
Federated Malay States	Cwt.	—	54	220	55
	£	—	112	407	108
Straits Settlements, total exports less total imports (c)	Cwt.	213,280	243,520	290,560	(d) 146,400
	£	454,794	515,643	569,188	(d) 279,280
British West Indies:					
St. Lucia	Cwt.*	492	1,485	305	72
	£	791	3,847	735	184
Jamaica	Cwt.*	—	—	12	(a)
	£	—	—	21	(a)
Trinidad & Tobago	Cwt.*	5,938	6,442	4,518	5,080
	£	15,753	15,373	11,102	11,860
British Guiana	Cwt.*	2,365	1,461	1,971	2,042
	£	6,375	3,879	5,265	5,089
Australia (b)	Cwt.*	4,531	2,761	3,944	2,373
	£	13,220	7,703	9,948	5,976
Fiji	Cwt.	2,649	1,830	1,580	(a)
	£	5,026	4,387	3,357	(a)
Zanzibar	Cwt.	196	361	1,246	1,692
	£	460	649	2,537	3,071
Tanganyika	Cwt.	40	60	(a)	(a)
	£	102	152	10	11
Kenya & Uganda	Cwt.*	17	23	48	84
	£	63	89	143	231
Mauritius	Cwt.*	1,297	1,164	1,050	488
	£	3,639	3,230	2,588	1,311
Seychelles	Cwt.*	371	220	99	72
	£	884	493	230	120
Dutch East Indies	Cwt.*	178,041	283,502	165,478 (e)	626,956
	£	424,682	599,614	348,834 (e)	1,286,769
Philippines	Cwt.	2,049,663	2,308,768	2,850,314	2,799,932
	£	4,060,682	4,539,865	5,110,200	4,825,220

(a) Information not available.

(b) All from New South Wales, and presumably made from imported produce. Years ended 30th June of year stated.

(c) Domestic exports should be not less than figure given, but may be about 1·0 per cent. higher if imports are retained for consumption.

(d) Figures are for 6 months—January to June, 1928.

(e) Java and Madura only.

* Converted from gallons at the rate of 8·715 lb. = 1 gallon.

Table D

Exporting country	1925	1926	1927	1928
St. Vincent	9,435	20,463	11,383	(a)
	1,475,000	1,700,000	2,675,000	3,360,000
	—	—	—	—
	1,484,435	1,720,463	2,686,383	3,360,000
St. Lucia	123,516	118,501	96,813	141,667
	495,000	400,000	1,020,000	1,575,000
	199,875	603,281	123,906	29,250
	818,391	1,121,782	1,240,719	1,745,917
Grenada	50,500	38,100	27,200	32,770
	115,000	340,000	315,000	595,000
	—	—	—	—
	165,500	378,100	342,200	627,770
Leeward Islands (excluding Inter-Presidency Trade)	156,614	207,018	496,082	(a)
	145,000	280,000	320,000	(a)
	—	—	—	—
	301,614	487,018	816,082	—
Jamaica	26,380,697	23,040,616	33,179,198	31,104,831
	7,835,000	22,015,000	18,035,000	17,075,000
	—	—	4,875	5,000
	—	—	—	(a)
	34,215,697	45,055,616	51,219,073	48,184,831
Trinidad & Tobago	8,633,981	5,041,036	6,463,765	6,799,655
	22,245,000	30,935,000	27,900,000	47,660,000
	2,412,313	2,617,062	1,835,437	2,063,750
	33,291,294	38,593,098	36,199,202	56,523,405
Bahamas	3,000	23,320	—	—
	—	—	—	—
	—	—	—	—
	3,000	23,320	—	—
British Honduras	5,785,158	5,512,560	5,929,834	(a)
	1,510,000	3,325,000	4,470,000	(a)
	—	—	—	—
	7,295,158	8,837,560	10,399,834	(a)

(a) Information not available.

Table D *(Contd.)*

Exporting country	1925	1926	1927	1928
British Guiana	1,363,280	815,917	334,185	321,635
	4,315,000	8,530,000	5,815,000	17,505,000
	960,781	593,531	800,719	829,562
	6,639,061	9,939,448	6,949,904	18,656,197
Ceylon	23,288,786	16,951,368	18,875,750	18,016,191
	568,430,000	604,850,000	495,540,000	494,165,000
	250,622,531	231,750,594	273,467,156	316,514,250
	842,341,317	853,551,962	787,882,906	828,695,441
British India	265,029	134,230	178,359	146,305
	515,000	8,175,000	4,535,000	505,000
	3,328,406	6,201,000	3,328,406	2,491,125
	4,108,435	14,510,230	8,041,765	3,142,430
North Borneo	292,653	668,693	681,208	(a)
	18,940,000	24,165,000	16,110,000	(a)
	122,281	147,062	220,594	(a)
	19,354,934	24,980,755	17,011,802	(a)
Sarawak	10,411	5,883	14,034	11,285
	3,565,000	5,910,000	5,980,000	9,260,000
	—	—	—	—
	3,575,411	5,915,883	5,994,034	9,271,285
Fiji	243,340	153,570	386,213	(a)
	120,665,000	139,340,000	132,800,000	(a)
	1,072,500	743,437	641,875	(a)
	121,980,840	140,237,007	133,828,088	(a)
Seychelles	61,000	83,900	12,500	21,500
	23,985,000	26,795,000	22,700,000	24,480,000
	150,719	89,375	40,219	29,250
	24,196,719	26,968,275	22,752,719	24,530,750
	—	—	—	—
New Guinea	195,755,000	229,030,000	238,065,000	(a)
	—	—	—	—
	195,755,000	229,030,000	238,065,000	(a)

(a) Information not available.

Table D *(Contd.)*

Exporting country	1925	1926	1927	1928
	—	—	—	—
Solomon Islands (d)	82,540,000	96,030,000	111,580,000	109,785,000
	—	—	—	—
	82,540,000	96,030,000	111,580,000	109,785,000
	—	—	—	—
Papua (e)	38,825,000	43,095,000	47,710,000	(a)
	—	—	—	—
	38,825,000	43,095,000	47,710,000	(a)
	—	—	—	—
Tongan Islands	68,790,000	69,960,000	56,260,000	78,355,000
	—	—	—	—
	68,790,000	69,960,000	56,260,000	78,355,000
	—	—	—	—
Western Samoa	72,595,000	61,250,000	58,325,000	(a)
	—	—	—	—
	72,595,000	61,250,000	58,325,000	(a)
	—	—	—	—
New Hebrides (Condominium)	36,855,000	41,910,000	51,020,000	(a)
	—	—	—	—
	36,855,000	41,910,000	51,020,000	(a)
	—	—	—	—
Gilbert & Ellice Islands	28,460,000	31,705,000	12,720,000	(a)
	—	—	—	—
	28,460,000	31,705,000	12,720,000	(a)
Nigeria	188	1,453	203	350
	970,000	580,000	675,000	1,470,000
	—	—	—	—
	970,188	581,453	675,203	1,470,350
Sierra Leone	1,010	2,396	4,791	(a)
	—	—	—	—
	—	—	—	—
	1,010	2,396	4,791	(a)

(a) Information not available.

(d) Figures are for 6 months—January to June, 1928.

(e) Java and Madura only.

Table D *(Contd.)*

Exporting country	1925	1926	1927	1928
Gold Coast	160	4,495	145	218
	6,620,000	7,565,000	7,270,000	7,280,000
	—	—	—	—
	6,620,160	7,569,495	7,270,145	7,280,218
Zanzibar	527,066	630,090	775,036	608,034
(total exports	62,405,000	63,950,000	50,260,000	46,795,000
less imports)	79,625	146,656	506,190	687,375
	63,011,691	64,726,746	51,541,226	48,090,409
Kenya & Uganda	81,200	127,400	60,200	30,800
	7,825,000	5,505,000	3,680,000	6,740,000
	6,906	9,344	19,500	34,125
	7,913,106	5,641,744	3,759,700	6,804,925
	—	—	—	—
Tanganyika	38,115,000	36,740,000	36,335,000	46,590,000
Territory	16,250	24,375	1,500	1,500
	38,131,250	36,764,375	(a)36,336,500	(a)46,591,500
Mauritius	—	—	—	—
	4,270,000	4,920,000	6,870,000	6,965,000
	526,906	472,875	426,562	198,250
	4,796,906	5,392,875	7,296,562	7,163,250
Federated Malay	175,000	112,000	105,000	121,800
States	289,985,000	329,145,000	287,680,000	342,520,000
	—	21,937	89,375	22,344
	290,160,000	329,278,937	287,874,375	342,664,144
Dutch East Indies	136,304	207,039	138,838	* 27,467
	1,727,330,000	1,854,650,000	1,530,755,000	2,191,355,000
	72,319,156	115,172,687	67,225,437	*254,700,875
	1,799,785,460	1,970,029,726	1,598,119,275	*2,446,083,342
Philippines	6,170	10,375	1,000	1,186
	721,960,000	856,365,000	980,855,000	1,153,575,000
	832,675,594	937,937,000	1,157,940,062	1,137,472,375
	1,554,641,764	1,794,312,375	2,138,796,062	2,291,048,561

(a) Information not available.

* Converted from gallons at the rate of 8·715 lb. = 1 gallon.

THE PROBLEM OF SOIL ANALYSIS*

AT the present time the assistant staff of the Soils Division of the Rubber Research Institute are occupied principally in the analysis of soil samples sent in for advisory purposes. This work must be regarded as of considerable importance, for an advisory centre is an absolute necessity to the planting industry and it is clearly part of the duty of the Institute to endeavour to fill that urgent need.

The questions asked of the Soils Division may generally be expressed as one of two fundamental queries. Most usually the soil is known to present difficulties, and recommendations for amelioration are required: we are asked "How can this soil, of which I am sending you a sample, be made more suitable for the growth of rubber trees or a cover crop ?" Or the potentialities of the soil are not known and we are required to state them. The second question therefore is "How suitable is the soil, of which I am sending you a sample, for the growth of rubber trees or a cover crop ?" What actually happens in most cases, is that we receive a letter which states the problem and requests that a soil analysis be made to solve it.

More rarely the sample is simply accompanied by a request for a soil analysis, but our mere compliance with this request would certainly be followed by a demand for an interpretation of our figures. Quite obviously it is not the figures but the soil expert's opinion that is of value: in fact the figures are only sent to inquirers to be filed as an interesting souvenir. This remark is not a cynicism but a warning; for it is highly probable that in the not-too-distant future advisory soil scientists will be employing methods of soil examination which, while they will answer questions on fertility with greater precision than the methods at present in use, will not afford any neat tables of percentages to send along with a letter of recommendation.

Faced by a table of the results of a soil analysis, the planter runs his eye down the columns and enquires "What's bogey ?" or words to that effect. Unfortunately the figures are not as easy to interpret as a golf card. It is the purpose of this article to comment on their interpretation and to discuss some of the problems that arise when an attempt is made to estimate soil fertility and manurial needs by means other than those of actual field experimentation.

Soil Formation and Constitution.—There are two kinds of soils, primary and secondary. A primary soil results from the decomposition *in situ* of an igneous rock such as granite or basalt, while a secondary soil is produced when a primary soil is washed away and deposited as mud or silt on a river flood area or in an estuary. Igneous rocks have a definite crystalline structure, the whole mass being a mosaic of very variously sized crystals of quartz and numerous other minerals. Under the influence of such factors as temperature fluctuations, the age-long action of percolating water and the attentions of numerous micro-organisms, the rock integrates wherever it is exposed. It is interesting to reflect that the rotting of a rock, though infinitely slower than the rotting of a mass of animal or vegetable substance, is, at any rate, in part, effected by very similar agencies.

* By C. Falconer Flint in the *Quarterly Journal of the Rubber Research Institute of Malaya,* Vol. 1, No. 3, September, 1929.

When a rock rots, the minerals other than quartz break down to a substance known as clay, while the quartz crystals may remain quite unaltered and, as sand, constitute the coarser fractions of the primary soils thus formed. Clay is a substance which possesses many remarkable properties, and a word or two about modern notions of its physical structure may not be out of place. There is very sound reason to believe that each of the tiny particles of which it is composed has a hard mineral core, probably a flat flake of some mica-like substance, the rest of the particle being a thick jelly-like envelope surrounding this core. This mineral jelly or colloid (the soil contains also organic colloids of vegetable and animal origin) is of the utmost importance to the agricultural value of the soil, for it not only profoundly modifies its physical properties but is the store for the mineral food salts necessary to plant growth. Its composition and precise properties may vary within wide limits giving all sorts of different clays, but in its relation to plant nutrition one fundamental property is outstanding: this mineral colloid is able to absorb food salts from the soil water when they exceed a certain concentration and to yield them up again when the concentration falls below this value. The details of this process are highly complex and can hardly yet be handled mathematically, for the value of this equilibrium concentration alters with the innate properties of particular clay in question, with the quantities and proportions of the salts already absorbed and with those present in solution. A given clay has a definite saturation capacity for food salts: when this is completely satisfied, the soil is slightly alkaline and when the clay is very unsaturated, *i.e.*, contains a very small amount of absorbed plant food salts, the soil is very acid. As a generalisation one may say the degree of acidity of a soil depends inversely on the extent to which its colloids are saturated with so-called "available" minerals.

The Micro-Organic Population and Its Functions.—In addition to its mineral constituents, the soil contains humus and a population, very varied as to number and species, of micro-organisms—bacteria, fungi and protozoa. These last would appear to feed on the first two groups and thus modify soil properties in quite a secondary fashion, but the bacteria and fungi exert very definite influences on plant growth, both beneficial and harmful. To explain briefly and rather crudely we may say (i) they decompose the soil minerals and make them available as food to the plant, (ii) they take nitrogen gas from the air and fix it in a form in which it may eventually become available to the plant and (iii) they decompose dead animal and vegetable matter so that its mineral content again becomes available in the soil and its carbon passes into the atmosphere as carbon dioxide gas to be again taken in by the plant leaves and built into vegetable substance. Under adverse soil conditions process (ii) may be reversed and certain minerals may be converted into a form in which they cease to be useful and may even be harmful, *e.g.*, phosphates and sulphates may be reduced.

Thus the micro-organic population of the soil serve as the intermediaries between the stores of potential plant food and the plant. When dead vegetable or animal matter falls on to the soil, the activities of the micro-organisms cause it speedily to rot away making the minerals it contains available for the growth of other plants: not directly, of course, but by a very devious route; they are taken into the bodies of the organisms initially active in the decay and either excreted or remain in the organism until it becomes, living or dead, the prey of another tiny creature which by its own particular processes may excrete the minerals in one form or another. In the same way, should the decomposition take place under the right conditions, the nitrogen contained in the vegetable matter will become wholly or in part available as food to the living plants growing on the site. The carbon, hydrogen, and oxygen contained in the decomposing tissue are

finally liberated as gases and water. From the plant's point of view, this is all that could be desired, since plants themselves take their supplies of carbon, hydrogen and oxygen from the atmosphere or from rain, its condensation product.

The Importance of Humus.—But there is an intermediate stage in the decomposition of vegetable matter that is of great indirect importance to the life of the plant. This intermediate stage is the formation of humus, a dark brown structureless substance of great chemical complexity which has a remarkable power of absorbing water and swelling tremendously by so doing. It gives to a fertile soil, if unstained by iron, its characteristic colour and imparts valuable lightening and water-holding properties. In a moist cool soil, humus has a high degree of permanence, its decomposition under the action of the soil micro-organisms being very much slower than the processes that lead to its formation. It has another remarkable property —its power of holding certain mineral salts, essential alike to plant and to micro-organic growth, in a loosely absorbed condition and of taking them into that condition from the soil water in which they are dissolved. Humus can thus be considered, quite properly, as a perfectly stocked caterer for the food requirements of a whole host of soil micro-organisms, supplying them with the main necessities of life while they work to meet the requirements peculiar to themselves and in so doing accomplish much of direct or indirect use to the plant.

Nitrogen Fixation.—To take an important example, some devote their energies to the fixing of nitrogen from the air: they build it into their bodies and at their death increase the reserve of this important element available to the soil. Remark that they will only do this when the percentage of nitrogen in the humus falls below a certain value. Nitrogen is essential to the vital processes of all the micro-organisms, but the great majority, lacking the power to take this element from the air, must simply suffer a restriction of their activities should adequate supplies in the humus be lacking. Under these conditions, other foods being available in sufficient quantities, the nitrogen fixing organisms will respond to the slackening of competition by multiplying and flourishing exceedingly.

Micro-Organisms and the Mineral Nutrition of Plants.—Other organisms, it would appear, obligingly sit by and feed the plant roots; and in a remarkably simple and effective fashion. For a long time it has been established to almost everyone's satisfaction that plant roots absorb their food salts only as a water solution. More recent researches on the food requirements of plants, on the quantities of water a plant will "perspire" (its only excretory system) during its lifetime and on the quantities of these food salts present in the main bulk of the soil water, make it abundantly clear that the plant root must be able to tap a solution that is very much more concentrated. There is good evidence to believe that what actually occurs is as follows: a colony of organisms grow around a soil particle that satisfies their mineral food requirements. Lack of a particular food salt develops in the fine feeding roots of plants a latent property known as chemotropism, *i.e.,* when in water containing a feeble concentration of the desired food they will grow towards the region where that concentration is highest. Now the carbon dioxide gas excreted by the micro-organisms will make the region immediately around the soil particle, enclosed as it is by the film of slime they excrete, distinctly acid and this degree of acidity once imparted (*i.e.,* the buffer effect of the soil solution once overcome) the traces of organic acids also excreted by the organisms will give a very high degree of acidity in a strictly limited region. This acid water rapidly removes all the food salts absorbed by the mineral jelly surrounding the soil particle and, acting through the protective layer of jelly, dissolves further the mineral core of the particles. Some of the solution produced,

of much higher concentration than the surrounding soil water, diffuses out of the colony of organisms and forms a series of concentric zones of progressively decreasing concentration to lead the chemotropic feeding root to the mass of slime surrounding the particle. Here, as close as possible to the particle, the rootlet remains, flattening itself around it and feeding on a liquid of far greater concentration than anything that could be extracted by expressing or displacing the water from the bulk of the soil.

It should be pointed out that this process whereby colonies of micro-organisms dissolve and decompose soil mineral particles is not entirely independent of the presence of the plant root. By removing certain food salts as soon as they become available, the rootlets displace an equilibrium that would otherwise be set up and permit fresh quantities of the salt to be brought into solution. Sometimes the amount of one salt that can be brought into solution, depends on the concentration in the solution of another substance. In this case, supposing a particular plant to have a high requirement for both, it would get ample supplies of both: but a plant of another species which needed much of one and little of the other would allow a considerable concentration of the unwanted substance to accumulate and this would set up a condition of equilibrium and prevent further supplies of the wanted substance from dissolving. Granted certain conditions, this soil would then be fertile for the one species of plant and relatively unfertile for the other.

And let it be noted that we know regrettably little about the food requirements of the rubber tree at the various stages of its growth.

In the absence of any plant roots, the solution process is still applied very effectively to the soil mineral particles, if less rapidly. A state of equilibrium is, it is true, set up but the gradual diffusion of the concentrated solution of food salts through the film of slime upsets the balance and permits of fresh dissolution, while the concentration of the external soil water is instantaneously reduced to normal by the action of the mineral and humus jellies both of which, as has already been noticed, have the power to absorb food salts from solution.

Chemical Analysis of Soils.—How then is a suitable system of soil analysis to be arranged ? What is to be determined and how ? A method that has been in use for many years is to boil the soil sample for a lengthy period with strong hydrochloric acid and, after filtering, to analyse for the necessary plant food salts the resultant acid liquid under the assumption that this treatment will not only decompose the humus and mineral jellies but will also take as much from the actual mineral fragments of the soil as would ever, in the course of many years, be made available to a growing plant. This treatment certainly decomposes the jellies of colloids and it certainly attacks the mineral fragments, but over any period of time during which it would be practicable to employ it in a laboratory it does not affect anything like a complete decomposition of the minerals. Apparently, one could reasonably argue that such treatment with a strong mineral acid must be far more effective than any treatment that plant roots or micro-organisms could bring to bear on the mineral particles, but experimental evidence indicates the reverse to be the case. Experiments have been described in which soils have been subjected to prolonged extraction with strong hydrochloric acid and subsequently well washed with pure water until all traces of the acid were removed and, even then, certain plants were able to make some growth and to extract mineral salts for the purpose from the soil. Incredible though this may, at first sight, seem, a little reflection will soon demonstrate that on a basis of known facts it is not so very remarkable. A digestion with strong acid for 48 hours would be a lengthy and inconvenient business not often resorted to, while for plant growth persistent action over

3 months or 3 years is all one for the patient processes of Nature. Her reagents, applied as I have already indicated, are less powerful as regards acidity but they probably have other subtler and more vitally destructive qualities and they are certainly applied more intimately and with an immediate removal of all the products of dissolution as soon as they are formed.

Methods of ultimate analysis—that is to say, methods that completely decompose the soil particles however large or resistant they may be—can, of course, be employed with scarcely more trouble than the strong acid extraction. But such methods are quite obviously too violent for our purpose and the figures they yield represent a potentiality removed from practical significance by ages of geological time.

We might agree on some gradual method of decomposition, nevertheless capable of achieving complete solution of the soil particles in a reasonable period of time, and by making periodical analyses during the course of the decomposition, obtain figures showing the various rates at which all the potential food salts pass into solution. Such a method would be possible, but it would be a very complicated and lengthy process to perform on even a single soil sample. Let us assume that we have such figures available for a series of soils whose respective fertilities for a particular crop we wish to predict and compare. What further information, if any, do we require ?

Interpretation of Chemical Analyses.—We must first safeguard ourselves by admitting the possible existence of all sorts of unknown factors that may not be as yet suspected by Agricultural Science. Then we must know the plant's need of each of the mineral food salts at the various stages of its growth, remembering that the absorption of a much needed salt present in adequate quantities in the soil solution may be seriously hindered if other materials are present in proportions to which the physiology of this species of plant at this stage of its growth objects : thus we need accurate information on this possibility also.

We must next inquire about the plant's accessory food requirements, *i.e.*, whether it is necessary for healthy growth that mere traces of certain rare or unusual substances be present in the soil.

It is now of fundamental importance to consider the rate at which those decomposition processes which we have endeavoured to imitate in the laboratory will actually occur in the soil under natural conditions. For rapid decomposition of the minerals and preparation of the food supplies a healthy micro-organic population of marvellously diverse species, well balanced in numbers and in action, is required. The wrong species must be discouraged. This proper condition of the micro-organic population will be governed by the availability and proportions of the food salts present, by the humus content of the soil, by its physical structure and colloidal content, by the nature of sub-soil, topography, local climate; in fact by everything that can affect soil temperature, drainage and aeration, not forgetting such important matters as the nature of the vegetation carried and the extent to which it shades the soil and prevents evaporation and wash. Truly, where the factors governing soil fertility are concerned, there are "wheels within wheels." To say nothing of the now well-known fact that minute traces of rare minerals in the soil may either stimulate or inhibit a particular species of micro-organic activity to a remarkable degree.

It should be emphasised that while the existence and importance of all these factors has been demonstrated and even investigated in some detail, we are very far indeed from the position in which they can be handled mathematically for any given set of circumstances and the net effect of their interaction computed. So, from what has just been written, any attempt to predict or compare soil fertilities by laboratory work would seem a very difficult matter indeed.

In actual practice, the position is somewhat ameliorated by the fact that nature is an adept at making the best of a bad job. So while it would be impossible to arrange a series of soil samples in order of fertility on the basis of such an analysis, the figures obtained merely by the analysis of the strong acid extract of a soil will furnish certain useful information. It will give a rough idea as to what is easily available to a strongly growing plant, assuming that other conditions concerning situation, climate and sub-soil are favourable, and it will indicate any gross deficiencies. If there is a gross deficiency of any important food salt, the soil has obviously not even potential fertility: and since supplies of this food must be added before any sort of fertility can be developed, it also gives an indication of manurial needs. All the finer points of the complete problem of soil fertility are, of course, ignored, *e.g.*, the fact that a substance appears in the acid extract is no guarantee that most or indeed any of it is available to the plant root, and the fact that there exists a gross deficiency of a certain food salt in the soil is no guarantee that any addition of that food in artificial fertilisers will not immediately be locked up by this particular soil in an insoluble form in which the plant can make no use of it. The existence of both types of phenomenon is an established fact. But generally, if the site and climatic conditions are favourable and the necessary mineral salts are available at all, nature will contrive to arrange at least a fair degree of fertility. Beyond that, to attempt to arrange soils in order of fertility is quite impossible.

Available Nitrogen.—A few further remarks must here be made about the nitrogen supplies of the soil, since although adequate supplies of this element are essential for any sort of plant or micro-organic growth, mineral analysis of the soil cannot indicate whether a sufficiency would be available. Broadly speaking, nitrogen is present in the soil in three forms, viz., (i) in undecomposed plant tissues and in the bodies of micro-organisms. (ii) in humus, (iii) as nitrate. It is only as nitrate that plants (other than legumes) can absorb nitrogen, but the nitrate content of a soil, though easily determined, can only be regarded as the currency of the moment, since the soil colloids, which have such valuable powers of absorbing and holding in reserve soluble plant foods, are unable to absorb nitrate which is consequently washed out very rapidly by the drainage water. An analysis of soil for total nitrogen can easily be made, but nitrogen existing in forms (i) and (ii) can only be made available to the plant by the action of a healthy micro-organic population. Further the replenishing of this nitrogen supply by fixation of nitrogen from the air, can only be effected by an active micro-organic population; which assumes a plentiful mineral food supply, and the presence of decomposing vegetable matter from either properly applied green or farmyard manure or from a previous growth of vegetation.

Biological Methods.—From the foregoing paragraph it would seem that by far the simplest and most promising methods for the laboratory study of soil fertility and manurial needs would be those involving an actual study of the health, nature and activity of the soil micro-organic population. Such methods have, of course, been proposed and enough work has been done to show that this line of attack is a very promising one. In fact, so interesting are the results of this study that the need for research along these lines is of immediate importance to any organisation or industry interested in the laboratory examination of soil samples.

It has been written, and often quoted in this connection, that the plant's opinion of the fertility of the soil is to be preferred to that of the laboratory expert. In justice it should be added that this was written at a time when soil scientists were far less alive than they are today to the artificiality of conventional methods of soil analysis, to the reserve needed in interpreting them and to the fundamental importance of field observations to any such

work. Even at the present time, the ultimate answer to the question "How fertile is this soil in this climate for this crop ?" must depend upon direct experiment or experience in the field. In most cases, however, the cost of such trial in time, money and opportunity would be so heavy as to make it a commercial impossibility, so the ideal of the scientist has become even more emphatically that of the commercial man who consults him. They both wish to be able, one day, to learn as much about a soil by a few days' laboratory work as could be learned by years of experience in the growth of the actual crop concerned.

We are already a good step nearer that goal when we decide that if we cannot get the plant's opinion of the soil we can at least get the opinion of his tradesmen and general caterers, the micro-organisms. And there is, as is very well known, an extremely valuable way of predicting the rubber tree's opinion when clearing forest for a new planting; it consists in a critical observation of the quality of the jungle remembering that Hevea itself is a native of tropical jungles.

Mechanical Analysis.—At the present time, any sort of laboratory soil examination is or should be preceded by a mechanical analysis. When the practical man examines soil in the field he classifies it, according to the fineness of the particles which predominate, as clay, loam, sand, etc. His experience enables him to predict much from his observations—how the soil will respond to cultivation, whether it will drain well and be properly ventilated permitting free root growth and yet at the same time affording adequate mechanical support for the crop, and storing and leading up from the water table adequate moisture. Subconsciously too, as well as weighing the conditions as regards the air and water supplies of his crop he considers their effect in keeping the soil active (that is, maintaining a healthy and useful micro-organic population) and he realises that while an excess of clay will tend to make a soil foul and stagnant it is the clay and its associated humus that hold the food and water supplies. It is, as a matter of fact, a sound generalisation that the coarser particles of a soil have no actual or potential value as a source of food salts since they are simply grains of quartz. Now this field classification of a soil is subject to the errors and variations of personal judgment, so in the laboratory a rigid mechanical classification is substituted by subjecting the soil to a violent dispersive process to disintegrate all aggregated particles and then determining what percentage of the particles fall into the different size ranges.

Some Inherent Difficulties of Laboratory Examination.—In case of every laboratory method for soil examination there is one fundamental difficulty—that the soil is disturbed by removal from the field and preparation in the laboratory, it being, of course, impossible to replace it in its original structure. Such disturbance is bound to upset the equilibrium of the micro-organic population and to affect seriously the permeability to air and water. All properties vary with each layer of soil from the surface downwards, yet a sample can give only an average figure, since thorough mixing is essential. The alternative would be to examine a large number of samples from progressively increasing depths—this would be impossibly long for routine determinations and so vertical division is made only into "top-soil" and "sub-soil." The necessity of mixing together a number of samples and re-sampling to get a material representative of a large area further complicates the issue.

Another difficulty, and perhaps one of the most serious yet mentioned in this connection, arises directly from the necessity of studying a soil sample removed from its normal environment. A few words only must suffice to indicate it. There is every reason to believe that the store of food salts held by the mineral and organic jellies of the soil is replenished not only by further solution of the soil particles on the spot but by absorption from

the dissolved matter in the ground water which may flow along beneath the surface for a great distance or may rise from great depths. In such circumstances the value of a mechanical examination would be still further reduced.

Field Observations.—We are now in a position to take a comprehensive and understanding glance at the position from the soil expert's point of view when he is asked one of the two questions seriously referred to. He will first of all need all the field information available and, since it is quite impossible for him to make the observations himself in every case, he must rely on all relevant information being accurately supplied to him by the estate manager or assistant.

The soil scientist can consider only one soil type at a time—every variation constitutes a separate case. If he is unable to visit he should first be supplied with a contour sketch map of the area in question on which the extent of the soil type or types should be indicated. Since it is of first importance to get the plant's opinion of the soil the quality of the jungle or particulars of previous crops and the life history and present condition of the existing crop should be accurately described and any unusual treatment or circumstances should be clearly emphasised. For each soil type a profile should be described in detail, *i.e.*, the nature, sequence and dimensions of the various strata visible in a vertical section: such a profile should be as deep as possible and may be obtained from a road or stream cutting, from the wall of a hill side slip or in unfavourable cases, by digging. It should also be clearly indicated whether great variation in the profile occurs over the area covered by the given soil type.

An elementary knowledge of geology is of great assistance here and much useful information may be obtained with relative ease by using a simple boring tool. This can be made in any workshop by screwing together sections of $\frac{3}{4}$ inch iron piping, with coupling collars as required, the lower section terminated by a carpenter's auger and the upper by a simple cross-bar, the soil can easily be explored down to a depth of several yards. The tool is screwed down into the soil and loosened every few turns by lifting it several inches and working it up and down in the hole. A sample of the soil in which the auger is actually engaged may be recovered from the twisted blade by simply pulling it straight up.

Soil Sampling.—After considering this information, the expert may decide that a laboratory examination of a particular horizon of the soil profile would be helpful. In this sampling, a considerable amount of care is needed if the sample is to be truly representative of the soil type to be studied: a monograph could be written on the innumerable accidents that could make the properties of the soil in any particular spot most misleading as regards the whole area. A root or a piece of wood may have rotted there, a small animal may have died there, a fragment of bone might get included, or the whole nature of the soil may have been altered by the work of ants or worms, or soil from lower strata may thus have been brought up. The tearing up of the roots of a great tree, long since rotted and disappeared, may have brought up a large amount of the sub-soil. These few of the many possibilities must serve as examples of the pitfalls that are set for the unwary soil sampler. In practice they are avoided by using every care that the spot selected for sampling shall appear thoroughly normal for the area in every way and sampling at least six such spots scattered at random over the area. Thus a number of samples are taken and carefully mixed and the final samples taken from the mixture—usually after first air-drying and crushing.

A soil sample is always taken as a block: that is, a volume of the soil is isolated from the rest and everything within that volume is taken. There are several convenient ways of doing this. For surface samples a

piece of stove piping, a piece of thin-walled metal tubing or a cylindrical tin is forced down vertically and then dug out or withdrawn together with the core of earth it contains. Such a core is generally 2 inches to 3 inches in diameter and is taken from the surface down to a depth of 9 inches or 1 foot. A more elaborate and convenient tool may be made by sharpening the end of a piece of suitable steel piping, splitting it down one side fixing it to an iron rod with a wooden cross-bar. This is screwed down into the soil, drawn up, and the core forced out by working with a screw-driver or pointed iron rod through the slit.

The following method is convenient when sub-soil samples are required: dig a pit down to a little below the required depth and smooth off vertically one wall of the pit. Take an empty cigarette tin and after piercing a small hole in the bottom to permit enclosed air to escape, knock it horizontally into the soil profile at the required level until it is flush with the vertical surface and then dig it out with the enclosed soil.

The Present Position.—Unfortunately it is not possible to treat every soil type examined as a separate research investigation and to apply such of the most modern methods as would seem most appropriate: the demands on the advisory services of the Soils Division are too heavy. The length of time it takes to carry out even the simplest determinations is not generally realised by those who have had no experience of laboratory work. Efforts are being made in the Division to study the most modern methods of soil examination as regards their usefulness for local soil types, to devise others, and by careful selection and experiment finally to arrive at a routine programme that could be applied, rapidly and conveniently, to any soil sample by trained assistants, and that would at the same time permit of as accurate an estimation of relative fertility and manurial needs as the present position of Soil Science allows. The need for that sort of correlation work is keenly felt today by the advisory soil scientist. The most gratifying progress has been made by specialised research along particular lines but, if a metaphor may be permitted, the cross-country communication is still somewhat poor. This is far from being a matter for adverse criticism: it is the normal result of the rapid progress of a new science. Such work normally falls to the lot of those who undertake research work in the interests of industry and in performing this service for the rubber planting industry in this country, the Soils Division of the Rubber Research Institute has great opportunities.

In the meantime we try to satisfy the pressing present need for advisory work by the liberal and progressive interpretation of the results of field observations together with, in certain cases, the results of a simple and conventional routine laboratory soil examination. A mechanical analysis is made to determine the percentage of sand, silt and clay and thus to permit the classification of the soil and the making of certain deductions depending on soil texture and structure. The loss of weight after strong heating is noted and a determination of the amount of organic matter and of total nitrogen is made. A portion is treated with boiling hydrochloric acid and the extract is analysed for potassium and phosphorus. Thus any gross deficiencies of nitrogen, potassium and phosphorus are indicated, and the indication is of some value since if any such gross deficiencies exist the soil cannot be even potentially fertile. These three elements are those which temperate zone agriculturists have found to be most frequently limited in quantity and the addition of which, together with lime, has been found to be a practicable and paying proposition. In the absence of definite information, workers in the tropics must be content to follow this temperate zone practice. The need for research here is obvious, but research takes time. If and when the need is felt for other fertilisers, they will be manufactured

and marketed. Until then, in our advisory capacity, we seek only soil deficiencies that can be met with the fertilisers available. On the research side, it is another matter, but one which is outside the province of this paper.

In conclusion, the writer would end on a practical note, since he has endeavoured to write for the practical man. Although the determinations we make in the routine examination of a soil sample are definitely old fashioned, no pains have been spared to make the means by which they are carried out as modern, and consequently as rapid and as economical, as possible. Even so, such an examination of one soil sample takes three hours of one man's time and five hours of another's, to say nothing of work done in preparing and storing the samples, interpreting the results and drafting the reports. With the trained assistance at present available the capacity of the laboratory is thirty samples a month. If this work were done on a business footing, paying its own cost by the fees charged, a fee of from fifty to seventy dollars would have to be charged for each sample examined.

In the foregoing paragraphs the very obvious need for a laboratory method for determining soil fertility and manurial needs has been indicated. While emphasis has been laid on some of the difficulties of applying schemes of chemical analysis and other "dead" methods to this problem, and attention has been directed to the very promising micro-biological methods which have as their basis a study of the growth of living organisms in the soil, it has also been pointed out that the results of even a simple chemical analysis can be of great value if liberally interpreted to supplement field observations. Such a simple analysis is, however, a relatively lengthy and costly process. These remarks will, it is hopéd, afford data by which estate managers in Malaya may realise the nature of the services they ask for and justify themselves for the courtesy and patience they invariably show in their demands upon the advisory services of the Soils Division.

METEOROLOGICAL RESEARCH AND FRUIT PRODUCTION*

SOME EFFECTS OF THE WEATHER ON FRUIT PRODUCTION WITH SPECIAL REFERENCE TO THE APPLE CROP

PART I

THE WEATHER AND FRUITFULNESS

APPLES are grown in very many countries and their susceptibility to the influences of varying climates has been well tested. In this country they are grown in Kent and the Eastern Counties where the annual rainfall does not much exceed 25 inches, and also in the West of England where over 40 ins. of rainfall is often experienced. The apple district of Nova Scotia has a very heavy annual rainfall while that of British Columbia is less than 12 ins. In these districts and also in Tasmania and the United States of America the summers are rather dry and the winters cold and wet, whereas on the high veldt of South Africa where apples are grown, the climatic conditions are the very opposite, for the rainfall comes mainly in the summer, whilst the winter is, on the whole, dry with almost daily sunshine.

As the apple tree flourishes and gives satisfactory crops under these very different climatic conditions it might be thought that this plant is little affected by climate, an assumption, however, which it would be incorrect to accept. In fact, judging by the few investigations that have been made, the opposite seems to be nearer the truth, namely, that the climate (and especially rainfall, light and temperature), influences the tree and the crop it bears to a very marked degree.

CLIMATE AND FRUIT BUD FORMATION

It is necessary not merely to consider the effect of spring frost at blossoming time, which is a popular and annually recurrent topic, but to probe deeper and to trace the effect of climate on the growth of the tree and the influence that it brings to bear in causing the tree to form strong fruit buds, which are initially necessary for fruitfulness. To make this clear, it is necessary to ascertain the ordinary behaviour of a normal tree growing under varying conditions of climate and then, if possible, to trace therefrom the part that climate plays. This aspect of the problem has engaged the attention of research workers in this country, notably B. T. P. Barker and A. H. Lees at the University of Bristol Horticultural Research Station, Long Ashton, Bristol, from 1915, and their results are given in a series of papers in the Annual Reports of that Station for the years 1916 to 1920.

TREE GROWTH IN A NORMAL SEASON

From a study of the growth of the apple trees in the plantations at Long Ashton, Bristol (where the annual rainfall is high), these investigators came to the conclusion that three distinct stages in tree growth could be

* Paper read by H. V. Taylor, O.B.E., B.Sc., A.R.C.S., before the Agricultural Section of the Conference of Empire Meteorologists, 1929.

recognised. The first stage covered the period between approximately March 14th and April 12th during which an even and regular slow movement was made by all buds. This movement might be described as an awakening from the winter sleep of all buds in response to the stimulus of warmth.

With the passing of this stage, soil moisture diminished, whilst a very uneven extension growth was made by the different buds. The terminal buds seemed to have a preference for they grew much faster than the others; less growth was made by the buds in the middle of the shoots, whilst those at the base remained more or less stationary. This was regarded as the second stage and the period lasted from approximately April 12th till May 20th.

The tree growth then entered the third stage; bud growth slackened very considerably; only a few buds at the apex continued to form *woody* shoots, and these one by one came to a standstill so that in a normal season growth was completed by about August 15th. Such was the behaviour of an apple tree growing at Long Ashton in what might be termed a dry season.

TREE GROWTH IN A WET SEASON

In the wet seasons it was noticed that the bud growth instead of stopping in the middle of August was continued until September 30th with the result that the wood of the tree was not properly ripened and much wood unfurnished with fruit buds was formed. As will be shown later this extended autumn growth in wet seasons plays an important part in rendering trees unfruitful, for this continued growth uses up the food material and prevents the tree from laying down food reserves which are so necessary for flower blossoms and fruit production. A continued study of this subject convinced A. H. Lees of the very great influence on fruit production of this summer and autumn rainfall, for in an article published in the *Journal of Pomology and Horticultural Science,* Vol. V., No. 3, July, 1926, he analysed the influence of summer rainfall and previous crop in the fruiting of apples. He described the normal growth phase of the apple and concluded:

> "that just as the basal buds are the weaker so the fruit spurs developed from them are weaker. So weak are they that it may be years before they attain sufficient strength to flower. Those nearer the apex are stronger and may flower next year, whilst the nearest may be so strong that their axis is three or four inches long and their terminal a wood bud and not a flower. There is therefore a distinct gradient in strength; the weakest are too weak to form flowers, the medium are just in the right condition, while the strong do not cease growth in length soon enough in the season to *store sufficient food for flower production.*"

It is thus suggested that to be in a fruitful condition the growth of the tree should cease early—not later than the end of July—so that reserves of food material may be stored within. Stimulated by summer and autumn rainfall, tree growth beyond that date may be prolonged which results in the using up of the food material, and in preventing the laying down of sufficient reserves to make strong and fruitful buds. In other words late summer growth—which is the result of excessive rainfall—is parasitic on the food supply that normally should be laid down as reserve for the buds.

SUMMER RAINS AND CROP

It was recognised by Lees that the crop of growing apples would also make heavy demands on the food material, and in consequence he considered this factor (the crop) and the summer rainfall as the predominating influences on the future fruitfulness of a tree. From a study from year to

year of these two factors he found that it was possible, with certain exceptions, to forecast with some accuracy the size of the crop to be expected. The exceptions are explained by abnormal Aphis attacks or the adoption of fresh methods of manuring or pruning, and if these exist an allowance must be made. Briefly, in forecasting, the grower was advised to make use of the following scheme:

Crop.	Rainfall.	Estimated succeeding Crop.
Heavy	Wet ...	Very poor
	Medium ...	Poor
	Dry ..	Medium
Medium	Wet ...	Poor
	Medium ...	Medium
	Dry ...	Good
Light	Wet ...	Medium
	Medium ...	Good
	Dry ...	Very Good
None	Wet ...	Good
	Medium ...	Very Good
	Dry ...	Very Good

A. H. Lees even went so far as to suggest that it was quite possible to throw trees into continuous cropping by regulating the manurial and "water factors" in the right direction. An alteration of the "water factor" can be effected by temporarily withholding manure, by cropping with a cover crop and by the practice known as "ringing."

RAINFALL AND GRASS ORCHARDS

Another observer of the effect of rainfall on fruit growing is A. H. Hoare, who, in his book "The English Grass Orchard," expressed the view that:

> "It is hardly possible to grow fruit successfully for market in a district receiving anything in excess of 40 ins. of rainfall. At between 30 ad 40 ins. fruit may be grown, but the orchards are mostly on the grass orchard principle, as we find on the Bristol side of Gloucester and in Somerset. In the regions of 25 to 30 ins. fruit may be grown in either cultivated or grassed land. Below 25 ins. fruit will do well on holding land. It might be laid down, therefore, that the best fruit districts are those with an average rainfall not higher than 30 ins.

Certainly, the fruit growing districts in England are in regions where the rainfall is similar to that suggested above. In Switzerland and Austria, where, generally, the sunlight intensity is far higher than that of England, the trees are not harmed by further supplies of water, but rather benefited, so it seems that rainfall—important as it is—is not the sole factor regulating fertility. As just indicated, intense light has a decided influence.

THE INFLUENCE OF LIGHT ON TREE NUTRITION: THE CARBOHYDRATE NITROGEN RATIO

The amount of summer rainfall and the light intensity influence the internal condition of the tree, which governs its fruitfulness or unfruitfulness.

Certain American research workers, especially Kraus and Kraybill, have attempted to measure this internal condition by ascertaining the ratio of carbohydrate to nitrogen present in the cell sap—a method which has aroused much interest.

The amounts of carbohydrate and of nitrogenous substances in the cell sap depend very much on the activities of the leaves and roots respectively. Under the action of bright light, the leaves are able to synthesise, from the carbon dioxide and water vapour, taken in from the atmosphere, some of the simple forms of carbohydrates; and these types of food material are essentially products of leaf manufacture. The amount of carbohydrates manufactured by the leaves naturally depends on more than one factor, but as the action is one depending on the influence of light on the chlorophyl, the intensity of light more or less exercises a predominating influence. In summers of intense light more carbohydrates are manufactured in the leaf than when dull light is experienced.

On the other hand, nitrogenous substances in the cell sap find their way into the plants in solutions absorbed by the roots, for it is the watery solution that is taken up by the root hairs. If the soil water is deficient, less of the nitrogenous constituents in the soil are dissolved, and a smaller quantity is taken up by the root hairs. Where the summer water supply is abundant and the soil is heavily supplied with nitrogenous substances, there need be no check on the entry of nitrogenous matter into the plant.

THE WORK OF KLEBS, KRAUS AND KRAYBILL

An American worker Klebs, has found that plants remain vegetative in bright light with a plentiful supply of water and nutrients, or in moderate light with a moderate supply of water and nutrients, but that they blossom after growing in *bright* light with a *moderate* supply of water and nutrients. Klebs apparently did not attempt to explain the reasons for this. Then came Kraus and Kraybill who in experiments found that most of their fruitful tomato plants were *moderately low* in nitrogen and high in carbohydrates. Fruitfulness then was associated neither with the highest nitrates nor with the highest carbohydrates, but with what the workers termed a condition of balance between them.

The limitation of nitrates or the limitation of carbohydrates resulted in a suppression of growth in tomatoes. When carbohydrates and nitrogen were adjusted relative to one another, rapid vegetative extension resulted. Where carbohydrates were in excess such an adjustment was secured either by increasing the nitrogen without decreasing the carbohydrate or by decreasing the carbohydrate without increasing the nitrogen. In both cases the relation of carbohydrate to nitrogen would be the same, but the total amounts were greater in the former than in the latter case, a condition reflected in the amount of growth resulting. The ratio of the carbohydrate to nitrogen determined whether the plants were to be fruitful or unfruitful, whereas the amounts present influenced the size of the crop.

Since this discovery was made known, much further work has been done regarding the connection between plant fruitfulness and the *carbohydrate nitrogen* ratio, with the result that the hypothesis has been firmly established by most workers and it is accepted in most countries. Whilst the exact rules for managing fruit trees to make them fruitful still remain hidden, the discovery marks an important step forward, establishes a new principle and makes it possible for the observant person to carry out the management of his orchards in a more intelligent manner. In fact it is seen that the fruitfulness of fruit trees in all countries rests on a scientific basis and the method of treament and manuring must be varied from country to country to offset the weather effects, if this proper balance between the carbohydrates and the nitrogenous substances is to be maintained.

In the U.S.A., where the summer rainfall is small and the light intensity is very high, it is conceivable that the leaves and trees are able to store up vast quantities of carbohydrates, and that in consequence fruit trees

would respond to dressings of nitrogenous manures. Actually this has been found to be the case and is instanced in the following paragraphs taken from the U.S. Department of Agriculture Year Book, 1925.

NITROGENOUS MANURES IN AMERICAN ORCHARDS

During the past 15 or 20 years much experimental work has been done in the use of commercial forms of plant foods in orchards . . . . . At least three oustanding results have come from these investigations:

(1) "Of these results, first, may be mentioned the demonstration that many soils when managed so as to maintain an abundant supply of humus, and when properly tilled, apparently yield all the plant food that is necessary for maximum fruit production.

(2) Another result, and one opposed to earlier teachings is the widespread absence of favourable response of fruits to potash. It was long held that fertilisers high in potash should be used liberally in fruit growing. Many tests, widely distributed, have failed to demonstrate any general response to applications of this plant food, especially on soil types widely used for deciduous fruit growing.

(3) It was long taught that nitrogen, and especially in quickly available forms, should be applied to fruits with much caution or else an undesirable and harmful stimulation of vegetative growth would occur. In the demonstration, not only have baneful results failed as a rule to appear, but to the contrary, the use of nitrate of soda or other quickly available forms of nitrogen, in even rather liberal quantity, has given more widespread and more generally beneficial results than any one fertiliser treatment in the growing of deciduous fruits."

POTASH FERTILISER IN ENGLISH ORCHARDS

Trees in England growing in a soil more abundantly supplied with summer moisture, and working in a duller light, are more likely to have a greater root activity in absorbing nitrogenous substances, and to manufacture relatively less amounts of carbohydrates. In other word the carbohydrates may be too low and in consequence trees (especially those growing in the West) are more likely to respond to such manures as potash which helps the plant in some unexplained way to make the most effective use of sunlight, than to dressings of nitrogenous manures alone. The experimental work done at Long Ashton by T. Wallace has shown this to be the case. Very many cultivated orchards, particularly those on the light soils, have been found to produce unfruitful trees, which make little or no response to nitrogenous matter, but become more healthy and productive after repeated annual dressings of potash fertilisers. Wallace's experiments and the results of the soil survey work in England during the past four years have shown that the leaves of the trees in these orchards are in a poor condition, commonly called "scorch," which is known to be associated with potash deficiency. When potash is added such trees improve; fruitfulness is restored or improved and increased growth is made.

Where fruit plantations in England are cropped also to grass, the roots of this cover crop compete with those of the trees for both water and nitrogenous fertilisers, and in time the leaves on the trees—even those growing in the west of England—gradually lose their dark green foliage and take on a yellowish light green colour which is said to be a sign that the nitrogenous substances have become too low. In such cases nitrogenous manures have been found to have beneficial effects in improving the fruitfulness of the trees both in quantity and quality of the fruit produced.

If this correct balance between the amounts of carbohydrates and nitrogenous substances is an essential condition to the fruitfulness of the tree—and all the experiments on the point seem to confirm that such a balance *is* essential—then the management of orchard fruit resolves itself into an adjustment, by pruning, manuring or cover cropping, of the inequalities produced by the natural soil and the prevailing weather in each locality. Of these it seems that the prevailing weather—rainfall and sunshine—is the more important, for the chemical or even physical analysis of the soil seems to provide little information as to its suitability for fruit growing or to provide any pointer as to the proper manurial dressing.

FRUIT SOIL SURVEYS

This does not mean that the fruit soil surveys that have been carried out in the past are useless or that those now being conducted will yield valueless results. It does mean, however, that the surveys must be made in a different way so that the reactions of the trees (in growing and cropping) on soils in any locality must be recorded as additional important factors for these give an intelligent observer a greater understanding of the conditions than even a detailed study of the chemistry of the soils. The appearance of the foliage of trees, their rate of growth, their fruitfulness or unfruitfulness, and their susceptibility or resistance to many diseases and pests are visible expressions of balance or lack of balance in the cell sap produced by the local soils and the prevailing weather. It is on these lines that the present fruit soil surveys are being pursued in England with very hopeful results. Up to the present the surveys have been of fruit on the soils in the Wisbech Area where the water table was thought to be more or less constant; on the old Red Sandstone in the West Midlands; and in West Cambridgeshire. Other surveys are contemplated or are in progress for trees on the soils (mostly sands, Lias clays and marls) in Worcestershire and Somerset, and on the varied soils of Kent.

Such surveys are providing information of the greatest value to the Advisory Service so that its members in future will be able to tackle the fruit problems with which they are confronted, with intelligence and a better understanding. Fruit trees in Worcestershire—where the rainfall and sunshine are fairly uniform for the whole county—react very differently when planted on the sands, the Lias clays or the marls, though in main the reaction is fairly regular on each type of soil. Stunted and hollow trees with much leaf scorch and signs of susceptibility to "die-back" on the sands give a striking contrast to the vigorous and healthy trees on the marls, or the large though somewhat chlorotic trees on the Lias clays. These strikingly different results are produced by the soils and the prevailing weather. Under different weather conditions trees on similar types of soils would react quite differently. It is the recognition of the combined effect of weather and soils in the growth of trees and their fruitfulness that is preparing the ground for a more intelligent method of orchard management for trees on each soil type in any locality.

So hopeful have been the results from the soil surveys made on these lines that the need for their extension to all the fruit areas of this country is admitted by those concerned. It is a line of investigation worthy of the utmost support by Departments interested in agricultural meteorological research.

Whilst this influence of the weather on the fruitfulness of trees seems the most important to the author it is a view that would not be universally accepted, for where the effect of weather on the fruit crops is in question, the majority of people think in terms of frost damage at blossom time. It is therefore advisable to set out in Part II of this paper the more modern views on the latter subject and also the methods that have been tried to prevent frost from damaging the blossom.

PART II

FROST DAMAGE TO FRUIT BLOSSOMS

When the fruit trees are in full bloom growers are very apprehensive of the weather conditions and fear wholesale destruction as soon as temperature falls to a low point. Frosts are feared by most, and winds by some, though a few suggest that the danger has been much over-rated. A. H. Lees of Long Ashton, for instance, has cited a case of plums which were in full bloom when there came a snowstorm which covered the plums completely. Later in the day the snow partially melted and toward night froze again. All night the blooms were locked in ice and dire prophecies of failure were made. Actually a heavy crop was set. In consequence Lees contended that the danger from spring frost was exaggerated except in certain situations where, owing to the configuration of the land, a natural reservoir for cold air was formed.

In the spring of 1927 severe frosts occurred throughout the various parts of Kent (England) during April when the temperature fell to 19° (thermometer on grass at East Malling). Wholesale havoc was expected and no doubt much damage was done, but it must be recorded that the apple crop in that year was above the average though the other fruits were somewhat below. Experiences such as these lead people openly to say that the spring frost is a bogey when actually there are times when spring frosts may be very harmful. At the East Malling Research Station records of both weather and crops are kept and it is interesting to set out the notes on both that were separately recorded each year in the annual reports. The results are as follows:

RELATION OF FRUIT CROPS TO SPRING WEATHER AT THE EAST MALLING RESEARCH STATION

Year	Spring Weather Report	Fruit Crop Report
1924	Temperature departed little from normal.	Very heavy crop of small fruits and apples.
1925	Normal.	Heavy crop of apples and black-currants. Raspberries affected by drought. Plums and pears disappointed.
1926	First days of April summer-like when plums, early cherries and apples were in blossom. Conditions during blossoming wet and cold.	Plums above average. Black-currants average. Early apples and early cherries good. Late flowering varieties poor.
1927	Devastating frosts during April, especially April 27th and 30th.	Good blossoming but frost damage. Apples below average, others poor. Black-currants the most satisfactory.
1928	Ground frosts at blossoming time of similar severity to 1927, but not so destructive to crops.	Apples good. Pears failed for third time. Frost and cold winds said to be responsible. Plums variable.

It will be seen from this that heavy crops were obtained in the years 1924 and 1925, when the weather was normal, but that in 1926 the fruit that came into blossom during the cold, wet period gave poorer crops than that which blossomed under good conditions. In 1927 frosts in late April were followed by inferior crops and the same occurrences, though less marked, took place in 1928.

COUNTY REPORTS OF FROST DAMAGE

Consequent on very severe frost at the end of April, 1927, the Ministry of Agriculture called for special reports at the end of May concerning the effect of these frosts on the fruit prospects. Twenty-nine reports were received and all made mention of severe damage to the fruit blossoms. Here are a few examples :

Hampshire.—Strawberry blossoms that were open were attacked. The embryo flowers were also killed, particularly the style and stigma. High elevations as well as low caught the frost (8-15° F. registered) equally. The pick of the blossoms were killed and there is little high-class fruit to come—though the "back fruits" have made a good recovery.

Worcestershire.—First Reporter.—Practically all fruits have been affected but more especially the plums and cherries, some varieties of plums losing 95 per cent. of the blossoms. Apples were late in coming into bloom and with the exception of "Grosvenor" they have escaped serious damage. Most varieties of pears have been badly damaged.

Worcestershire.—Second Reporter.—In the low-lying parts the damage to plums is estimated at 90 per cent. as the result of temperatures as low as 14° F. On the favoured high ground the effect of the frost is hardly perceptible. In some cases it is very difficult to account for the frost damage in plantations joining one another, the one being badly hit whilst the other has scarcely suffered.

Pear bloom was unusually profuse just at the time of the frost with the result that there are no pears, except Williams.

Eastern Counties.—The incidence of frost damage has been most erratic. Orchards protected by rows of trees or closely planted have escaped the most lightly, whilst in bleak positions the damage has practically wiped out the crop.

Norfolk.—On the whole, plantations of black currants lost about 50 per cent. of blossoms through the frost. A few plantations escaped injury.

Hereford.—A frost varying from 11-13° F. occurred on the night of April 29th-30th, accompanied by a strong wind N.W. to N.N.W. Only fruit blossoms protected from this wind and at fairly high altitudes escaped damage. In many orchards the crop was totally lost but in exceptional situations very little damage occurred. Within these extremes, representing the bulk of the plantations, damage of varying severity was experienced

Kent.—Most frost damage appears to have been experienced in the low-lying pockets, though some damage was experienced at all altitudes up to 400 ft. above sea level. High districts escaped. Generally, the frost damage has reduced the total crop very much less than was at first anticipated.

The following are taken from reports received in 1928 :

Warwick.—A series of frosts—varying in intensity from 5-10° F.— was experienced between the 16th-23rd of April, with the result that much damage was done to fruit trees in flower. Very few apples were in flower and on some sites but little injury is apparent. In low-lying positions, although the petals of the unopened flowers are intact, yet the vital organs have been destroyed. Plum trees had just passed the flowering stage and a large proportion of the fruitlets are black—though a sufficient number have escaped injury.

Norfolk.—Bitter cold winds and frosts at night up to 10-12° F. have damaged 25 per cent. of the plum blossoms. Other fruits are less affected.

Kent.—Weather conditions during March and April have been adverse for insect pollination ; otherwise injury is very slight.

Isle of Ely.—Ground frost on April 6th, 12° F. Apples, frost injury negligible. Plums, some injury. Pears, most blossoms ruined. Strawberry flowers blackened.

Worcestershire.—Apples—some frost damage, particularly in the valleys. Victoria plums severely damaged on the low ground. Strawberry flowers blackened.

Devon and Cornwall.—Frost on 16th April. Pears were caught in full bloom and browning took place. Plums suffered severely. Strawberry blooms blackened.

Cambridge.—There is no evidence to show that there has been much damage. Plums in exposed areas have suffered from cutting east winds and in sheltered spots where frost pockets have formed. In the main I think that the dryness of the air to a large extent saved the situation.

Middlesex.—Plums everywhere seem to have suffered. Pear injury is not so general and apples show no damage.

Herefordshire.—A frost on March 12th from 18-22° F. at which time the Baldwin black currant was just showing flower. The blossom trusses are quite brown (½-in. long) and the loss over the whole area will be 5 per cent.

These reports made by experienced horticulturists as the result of personal observations clearly show that under certain conditions intense cold may actually kill the vital organs of the blossoms of all kinds of fruit and thus make it impossible for such blossoms to produce fruit. The degree of cold seems important, though severe damage seems to result only when the fruit (with certain varieties excepted) is either in full blossom, or nearly so, and becoming ready for fertilisation. The damage seems to be intensified when a cold and biting dry wind is also present.

There is a unanimous opinion, too, that frost injury is more severe in valleys and low-lying ground, though many observers continually refer to damage in "frost pockets"—whatever that may mean—and also state that "air drainage" prevented frost damage.

If any wide investigations were contemplated it would seem advisable to study tracts of land to discover the altitude below which it is inadvisable to plant fruit, and to find out exactly the causes of a "frost pocket" in an otherwise frost free area and to ascertain what "air drainage" means also.

FROST SUSCEPTIBILITY OF CERTAIN VARIETIES

In the above-mentioned enquiry, observers were asked to notice particularly the comparative injury caused to the several varieties of fruit with a view to ascertaining whether all were equally affected or whether some appeared to possess more resistance than others to frost. The results obtained are more definite and interesting than were expected.

The damage done to several varieties of fruits, classified under the headings of "severe damage," "damage," "slight damage" and "unaffected" was as follows:

DIFFERENCES BETWEEN VARIETIES OF FRUIT IN THE DEGREE OF DAMAGE CAUSED BY FROST

Severe Damage	Damage	Slight Damage	Unaffected
		Apples	
Bramleys	Court Pondu Plat Beauty of Bath	Cox's Orange Stirling Castle Worcester Pearmain Lord Grosvenor James Grieve Warner's Lane's Early Victoria Bismarck Lord Derby Newtons (var.) Allington Ellison's	Wellington Irish Peach Royal Jubilee
		Plums	
Victoria Monarch Greengage	Pershore Egg	Czars River's Early Prolific Ponds Seedling Purple Pershore Belle de Louvain	
		Pears	
Conference Louise Bonne de Jersey Beurre Bosc. Williams Beurre Hardy Clapp's Favourite		Fertility Durondeau Doyenne du Comice	Hessle
		Black Currants	
	Baldwin Boskoop Edina	Seabrook's (Black)	
		Gooseberries	
Whitesmith White Lion Gunner	Lancer Careless Keepsake	Lancashire Lad	
		Strawberries	
Sovereign Laxtons	Bedford Champion The Duke	Mde. Kooi Paxton Stirling Castle	

Naturally there was some conflict of opinion concerning some varieties but unanimous opinion existed both in 1927 and in 1928 that with apples Bramley suffered the most damage, and that Cox's Orange, Lane's, Worcester Pearmain, Lord Derby, Allington and Newton Wonder, were less susceptible.

With plums the variety Victoria suffered the most, Pershore the next, whilst Czar escaped with slight damage. These results were confirmed in 1928.

Of pears Conference and Clapp's Favourite were the most affected in all districts, and Hessle the least.

With blackcurrants the only positive result on which nearly all observers agree is that Seabrook's Black suffered the least.

With gooseberries Lancashire Lad seemed the most resistant and White Lion the most susceptible to damage. There was agreement that "Sovereign" Strawberries were severely damaged in all districts whilst Sir Joseph Paxton escaped with slight injury. A closer analysis of the respective behaviour must be left for future research workers who have a large and interesting field to explore.

So definite have been the conclusions regarding the susceptibility of Bramley apple, Victoria plum, Conference pear and Sovereign strawberry and also the definite resistance of several apples, Hessle pear, Lancashire Lad gooseberry, Seabrook's blackcurrant and Sir Joseph Paxton strawberry that it is clear that varieties differ considerably in their ability to withstand frost damage. An investigation of this kind can only point out the main problems and it must be left to the more careful and patient research work of scientific investigators to define more clearly the response to frost damage of the main commercial kinds. It is clear that the problem is important and worthy of further investigation.

RESEARCH WORK ALREADY ACCOMPLISHED

A certain amount of research has been done and it is proposed to set out in a concise form the facts on this subject that have been made known.

In the spring (April in England) the fruit buds of a potentially fruitful apple tree, receiving some stimulus from within, burst into blossom. The blossoms are composed of many parts; firstly there are the conspicuous pink and white petals—popularly called the apple blossom—whose main function is to attract insects to the flower; but having done this they fall and serve no further purpose in fruit production. The effective organs for this work lie within the petals; they are much smaller and much less conspicuous, and it is necessary to give some description of these and the functions they perform before the influence of the weather can be fully understood.

If the flower of the apple is examined there will be found, lying just within the pink and white flowers, a large number of thin filaments each carrying at the top little oval sacks, which on maturity—they do not all mature on the same day—burst open, scattering little yellow pollen grains, some of which get attached to the legs, wings and bodies of insects that visit the flower in search of nectar and are carried by these from blossom to blossom.

BLOSSOM FERTILISATION DESCRIBED

Inside this whorl of filaments there are to be found others (the stigma) which are somewhat shorter, fewer in number and much stouter, particularly so towards their apex. On maturity the ends of these become sticky, a condition which remains for 2 or 3 days. Again these do not all mature at the same time. The pollen grain pitching on these sticky substances is not

only held fast, but it absorbs water from the sticky substance, swells up and in consequence is stimulated to grow, which it does by sending out a germ tube. This tube is capable of pushing or dissolving its way down through the stigma filament into the swollen green tissue lying just at the top of the stem. The germ tube here reaches the sac containing the egg and has thus made a passage between the pollen cell and the egg cell.

These processes only take place under favourable conditions. Under adverse weather conditions the sticky mass may dry up, in which case the pollen cell is not stimulated to germinate; or, if the temperature be too low, the pollen again may send out no tube at all, or, if the germination is stimulated at a low temperature, the growth is so slow that the tube may dry out before reaching the egg sac.

It has been shown by research that pollen grains do not germinate at temperatures lower than 40° F, and even at temperatures below 50° F. the growth of the tube is so slow that a connection between the pollen cell and the egg sac is not effected in under 2 days, though the actual time varies considerably. A high atmospheric moisture during this period is desirable. In practice, of course, the temperature and the moisture vary considerably and it is conceivable that in almost every year a very large proportion of germinating pollen grains fail in the attempt whilst a few that grow under the more favourable conditions complete their growth and establish a contact. The proportion that do so in each year must vary according to the weather conditions.

When the aforesaid contact has been established, the male gametes of the pollen cell travel down the tube, enter the sac, and fuse with the egg cell, a process known as fertilisation.

Providing the nutrition of the egg cell is adequate and properly balanced, the fertilised eggs soon begin growth and cause a swelling of the green base by which sign growers recognise that the blossoms hav set their fruit.

The blossoms on a fruit tree are many and if all were fertilised and set fruit, it would be found that the tree would be quite unable to carry the crop. Actually only a small percentage of blossoms need to be "set" to give a full crop.

Research workers in the U.S.A., from an actual count, found that a 10 per cent. set gave a full crop, whilst Crane at the John Innes Horticultural Institution (London) found that a 5 per cent. set was sufficient for a full commercial crop. By spreading the time for maturing their pollen grains over many days, by having their stigmas receptive also over many days, and producing numbers of each far larger than could possibly be needed, the blossoms have provided for a considerable loss of their numbers without thereby causing a loss of crop.

It is only in years of exceptionally unfavourable weather—intense cold combined with continued dry winds—that the set is reduced below the "five per cent." When these unfavourable years come and bring their resultant small fruit crops, there is an outcry for means of protection against frost damage, and as a conclusion to this paper it is proposed to set out the views that are held at present on orchard practices for frost protection such as (*a*) smoke screens, (*b*) spraying, and (*c*) heaters.

SMOKE SCREENS

Realising that the earth at night radiates heat to the air the early workers attempted to prevent the escape of this heat by holding it near the ground under a cloud of smoke which could be produced without much difficulty by smudge fires. This smudging for a time was believed in and much practised, praticularly in California and Florida. However, when

quantitative data of both German and American workers became available for the comparison of temperatures in smudged and unsmudged areas (when the heat factor is eliminated) there was nothing to indicate that a sufficient saving of heat had taken place to make the smudge in itself of any great value; in fact, it was concluded from the investigations that "the retardation of nocturnal radiation by the smoke cloud played an insignificant part in frost protection." These results are surprising, seeing that the practice is of very long standing, for it is said to have been carried out by the Romans, and was much in vogue in the 16th-18th centuries in French and German vineyards.

COVERING AND SPRAYING

The protection of plants from frost by covering them with paper or cloth is effected through saving of the heat otherwise lost through radiation. The efficacy of this method is well known though it does not seem practicable for orchard use. Next came the attempt to protect plants by a water spray, but when this practice was investigated it was found that the sprayed blossoms were the more severely damaged. In fact the ice formation on the surfaces of the blossoms actually hastened the complete freezing and damage of the inside tissues.

ORCHARD HEATING

Whilst the investigations on "smudging" were in progress it became apparent that the smoke fires did in fact directly warm the air in the vicinity and in consequence the method of protection by orchard heating was tried and eventually found to be successful. It would at first appear impracticable to warm up the air in an orchard and persons unfamiliar with the true situation may be forgiven for believing that the heated air would rise to a considerable altitude and be lost. However, this is not the case. On a clear, calm night there is a relatively thin layer of cold air near the ground and much warmer air above. This condition makes orchard heating possible. The hot gases leave the heaters at a high temperature but rapidly mix with the surrounding air so that actually the whole mass is only slightly heated. This slightly heated air naturally rises, but not far, for it soon meets air from above of the same temperature as itself, when further upward movement is checked. Thus in many cases it may only be necessary to warm up the air of an orchard to a height of 30 to 40 ft.

The choice of the heater depends on many factors. A few large fires have proved ineffective, mainly because the upward movement of the warmed air rising from them is not checked as is the case with heated air from small fires and in addition a current is set up so that cold air is drawn in from outside and the valuable warm ceiling layer becomes broken up.

In those sections of California where orchard heating is practised, one hundred burners to the acre, using 1 gallon each of oil, are the most common. These will burn for from 7 to 10 hours, and in recorded experiments have been effective in keeping the temperature 5° F. higher than that of the unheated areas. Wind is a complication and often makes the heating effect of no avail. Fires of coal, coke, briquettes, wood and other waste products have been tried, but none have been found to give as sucessful results as oil. These substances often take too long to light and in the interval the temperature sinks too low and the damage is done. When once lit, too, they cannot be put out if (as often happens) the temperature rises, but must be left to burn to the end, when wastage occurs. Oil is free from these objections, for lighting is rapid and any or all of the lamps can be extinguished at any time when the danger has passed.

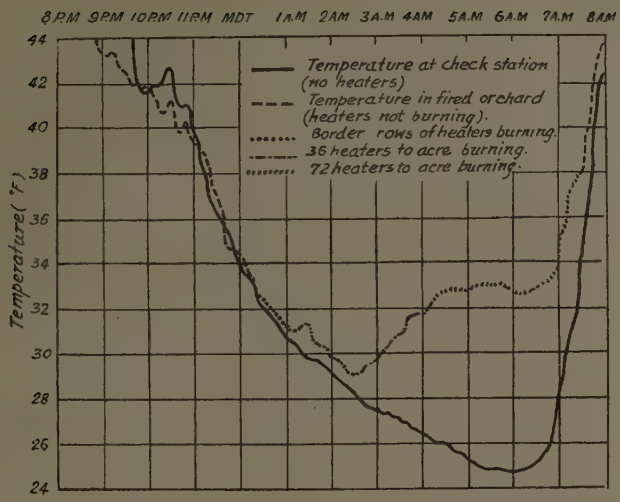

FIG. 1.—Continuous records of the temperature in an isolated 10-acre pear orchard equipped with 5-quart lard-pail oil heaters and at a check station outside. The check-station record indicates what the temperature in the orchard would have been without heating. The temperature was raised 8° F. with 72 heaters to the acre burning. Compare with temperature increase at a larger fired orchard on the same night as shown in Figure 2. Small green apples and pears at the check station were frozen solid on this night.

The writer thinks it unnecessary to give an account of the orchard heater, of the brand of oil used, of the arrangements for placing the pots in the orchards, or of the methods adopted for lighting the heaters, etc., for all particulars of these have appeared in Farmers' Bulletin No. 1588, issued in April, 1929, by the U.S. Department of Agriculture, and in the New Zealand Journal of Agriculture for June, July and August, 1928. It seems, however, essential to the discussion to record the results achieved and the expense involved.

The results are best shown by a reproduction of two graphs taken from the aforesaid bulletin, for these give the results of carefully recorded experiments. The one relates to a 10-acre orchard and the second to a 100-acre orchard.

In the control plot for the 10-acre orchard the temperature steadily dropped from 44° F. at 9 p.m. to 25° F. at 6 a.m., when the small green apples and pears were seen to be frozen solid. In the 10-acre orchard the temperature dropped in a similar way from 44° F. at 9 p.m. to 33° F. at midnight—when the border rows of heaters were lit. The temperature dropped but less sharply so that at 2 a.m. it was nearly 29° F., when 36 burners were started. This arrested the drop in temperature, and in fact secured a rise to above 32° F. by 4 a.m. It was necessary, however, to have 76 burners going from 4 a.m. till nearly 7 a.m. to maintain this temperature after which time all danger had passed. At 6 a.m. the difference between the control orchard and the heated orchard was as great as 8° F., *i.e.*, 25° F. as compared with 33° F.

The notes given on the graph for the 100-acre orchard are self-explanatory; and again show that orchard heating, when properly done, can maintain a satisfactory air temperature even over large acreages. Careful experiments made in New Zealand in 1928 over small areas gave somewhat similar, though perhaps slightly less successful, results.

COST OF ORCHARD HEATING

No figures of experiments in England are available to show the cost of orchard heating, but many accounts have been published for orchards in the United States. Firstly, there is the question of the number of times that the fires must be lit and this varies for the crop. and for the year. To protect citrus orchards during the winter months needs more firing and for longer periods than for deciduous fruits. In one recorded instance, for protecting 281 acres of lemons, the average number of times firing was required over a period of 14 years (1913-1926) was 17, with a minimum of 2 in 1914 and a maximum of 30 in 1923. In protecting orchards of deciduous fruits the average is said to be about 5 times annually.

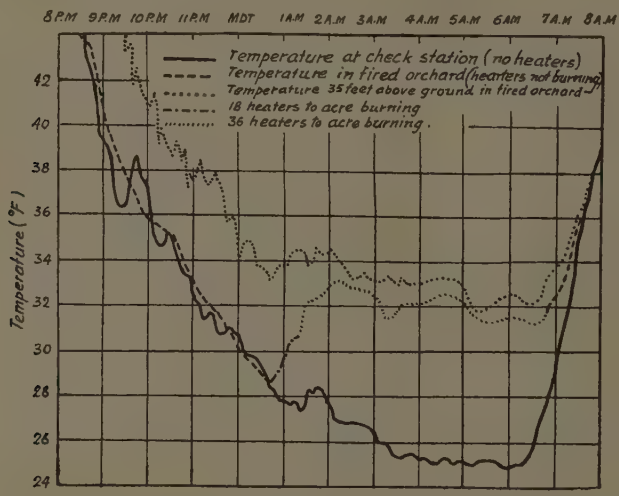

FIG. 2.—Continuous records of the temperature in a 100-acre pear orchard equipped with 5-quart lard-pail oil heaters, and at a check station outside. The check-station record indicates what the temperature in the orchard would have been without heating. The temperature 35 feet above the ground in the orchard equipped with heaters is shown by the dotted line. There was only about half as much temperature inversion on this night before the heaters were lighted as in the record shown in Figure 1. The temperature was raised 7° F. at this location, burning only 36 heaters to the acre. No heaters were lighted at any time during the night in the row in which the temperature station was located. Reserve heaters had to be lighted twice during the night to replace those which were burning dry. The fall in temperature about 3 a.m. and again at 5 a.m. was due to heaters burning low.

The cost involved falls under two heads, capital and annual operating costs. A typical cost for 40 acres of pears with simple oil heaters is said to be:

		Dollars
Total investment for 40 acres	...	3,269·00
Total annual cost ...	...	944·18
Or average annual cost per acre	...	23·60

For a 303-acre orchard of apples and pears, in which coal briquettes were used the cost was:

		Dollars
Total investment 303 acres	...	20,848·30
Annual cost per acre	...	27·89 in 1925
		49·33 in 1926
		39·16 in 1928

Kidson estimates the cost for heating orchards in New Zealand, with oil for three firings only being provided for:

	2 acres.	5 acres	10 acres.
Investment ...	£70 0 0	£156 12 0	£306 15 0
Average running cost per acre	£19 2 6	£18 0 10	£17 12 2

CONCLUSION

These figures clearly show that orchard heating is costly. Whether it is profitable seems to be a debatable point. The few growers who tried it in England soon gave the practice up. In the U.S.A., orchard heating has become a settled part of orchard routine in the citrus fruit sections; in others it has been in extensive use, but is now almost obsolete.

If the value of the crop per acre is high, as with citrus fruits, heating may be economically sound; if the crop value is low, heating is of doubtful wisdom. Frequently the yearly expense of orchard heating in America has amounted to £5 per acre; in some cases it has reached £10; so that while in some instances it has proved a profitable practice, in more cases it has not. At any rate, a recent booklet on American orcharding records that "orchard heating is not so common as it was some years ago. Certain areas have abandoned it altogether, in others only a few growers continue it. In some instances too much has been expected of it, but probably in the majority of cases it has been abandoned for the excellent reason that it has not paid."

The high cost of orchard heating and the uncertainty surrounding frost occurrences make it necessary for growers of deciduous fruits to rely more and more on what may be termed frost resistant varieties and it is to this aspect that the attention of research investigators is directed more particularly.

CROP ESTIMATES AND FORECASTS*

METHODS IN TROPICAL COUNTRIES

THAT crop estimates and forecasts have a value to trade is recognised in most countries and, in many, considerable expense is incurred in their preparation. There is a distinction between a forecast and an estimate which is not always observed. Strictly speaking, a forecast is a prophecy, an estimate before the event. A yield forecast is an estimate made before the crop is reaped; an estimate is made after the crop has been reaped. But as the final official estimate can only be an approximation it is perhaps permissible to refer to estimates made between harvest and the final return as forecasts, forecasts, that is, not of the crop but of the final return. A true forecast of yield can never be unconditional; it is made before the crop is harvested and there is always the possibility of the crop being damaged or even lost by last minute adverse weather conditions. A true forecast is, therefore, always conditional, and assumes that the weather conditions to harvest will remain normal. An estimate, on the other hand, is unconditional; it is made after the harvest has been reaped. The major value of an estimate to trade is its accuracy, that of a forecast lies very largely in its earliness. True forecasts are necessarily liable to error because they are conditional; nevertheless their earliness gives them a trade value which justifies an effort towards their improvement.

Factors to be studied.—Total production is the resultant of two factors, area, or acreage, and yield per acre. In plantation crops the former hardly enters into the question of forecasting, for where a crop takes some years to mature marked fluctuations in the annual acreage are impossible. The productive area can here be determined at comparatively small cost. It is in annual crops, crops like maize and cotton, that large fluctuations occur from year to year and that difficulties arise in any accurate determination of area at any reasonable cost. Where climatic conditions are such that only when these are favourable can a crop be grown, it is these conditions that will control area; where these conditions are such that they offer no check on the area sown, it is the cultivator's own judgment as to the relative value of his alternative crops that will determine the area. These latter conditions hold not only in a country like England where climate rarely offers any check to sowing operations but in an irrigated tropical area where any deficiency in moisture at sowing time can be made good artificially.

Statisticians have evolved a useful and delightful measurement of the degree of inter-relationship between two series of observations—the correlation co-efficient. It is useful because it expresses in a brief numerical form —ranging from + 1·00 through 0·00 to—1·00—a wealth of information; it is delightful because the calculation can be extended to give the true odds against any particular conclusion. These the bookie cannot know, these the layer of a stake at the roulette table does not stay to calculate, but here it is possible to say with accuracy the chance that the actual result will lie within any given divergence from the calculated figure. But the calculation requires a series of concordant data giving the relative values of the two series; and herein lies the main difficulty, for in relatively few countries are

* By Dr. H. Martin Leake, Sc.D., F.L.S., in *Empire Production and Export*. No. 156, August, 1929.

there a sufficiently large series of measurements of climatic factors, of areas and yields to enable the relation between climate and factors determining yield to be measured. It is in the main this difficulty which has limited the number of instances in which the method has so far been applied. A brief account of a few of these follows.

Some Examples of Method.—The cotton crop of Northern India may be sown on irrigation or on the first monsoon rains. The area of the latter varies immensely owing to the wide variations of incidence and amount of the early rains. It has been possible to forecast, with an accuracy greater than that of the official forecast, the area of unirrigated cotton of a tract limited to a single district. It is possible to do this by the 15th July, a date on which cotton is still being sown and which is well before the date of issue of the first official forecast. The irrigated area shows, as would be expected, no such dependence. It can, by the same method, be shown to be dependent on the cotton—wheat price ratio, dependent, that is on the relative importance of cotton and wheat in the estimation of the cultivator, and it is interesting to note that this dependence is greater in a district of the main cotton tract than in one which lies on the border of that tract. In the main cotton tract the cultivator pays greater attention than elsewhere to the price of the commodity. In the same tract wheat is the principal cold weather crop. It, again, is sown either with, or without, irrigation. The irrigated wheat area shows no dependence on the rainfall of the preceding monsoon, but the unirrigated area can be shown to be largely dependent on that rainfall. It is, in fact, possible to calculate what that area will be from the preceding monsoon rainfall and to do this some 15 days before sowing commences and with an accuracy greater than the official estimate published some two months later. In the Punjab even more accurate determinations have been made by taking into consideration other factors.

The above indicate what may be possible in the direction of determining acreage. More important from the commercial aspect is the question of estimating yield per acre. A reliable method of estimation of yield at the commencement of harvest, and one which would eliminate the personal factor, would be of considerable advantage to plantation managers and companies engaged in agricultural production. As an example of what is possible here, the results based on the records of a Barbadian sugar plantation may be given. The crop is laid down around the New Year and occupies the ground for some fifteen months. Given the daily rainfall data from June to December—eighteen months covering the date of sowing—it has been found possible to forecast the yield of cane per acre with an even chance of being within three tons of the actual yield. It has, further, been possible to extend the method to apply to the entire sugar production of the Island of Barbadoes. Results of a similar nature have been obtained for the yield of cotton on an Indian farm where, though by a more complex calculation, the monsoon rainfall is used as the basis of determination.

A considerable amount of work has been done in America in the above direction, and it has even been claimed that the American cotton crop can be estimated from weather data with an accuracy which exceeds that of the official estimates. It is a complicated calculation in which other than rainfall data are involved. Recently, too, the cacao yield on the Gold Coast has been shown to depend on the seasonal rainfall to an extent which renders it probable that the crop could be forecasted from the rainfall data were a sufficiently lengthy record available. But perhaps the most noteworthy effort to forecast yield comes from Mauritius. Mauritius is an island periodically swept by hurricanes and the attempt was made to find a reliable method of estimating loss for insurance purposes. To this end it was necessary to determine what the yield would have been had there been no

hurricane—a determination about as difficult as that of the length an illness would have been if the doctor had not been summoned. In spite of the difficulties, a result very successful, if not sufficiently convincing for the insurance companies, was obtained using again meteorological data as a basis for the calculation.

Practical Advantages.—The above indicate in very brief outline the advances which are being made in the direction of forecasting crops from the weather records. The practical advantages of such methods when perfected are patent; to the plantation manager, freedom from the personal element in making his estimate; to the trader, ability to make his own estimate independent of official agents other than those of a weather bureau; to Government, freedom from a somewhat complicated and expensive system of crop reporters. But there are other advantages which are not so obvious. The fact that it is coming within the range of possibility to forecast yield indicates a growing knowledge of the relationship existing between the crop and the climatic conditions. It means a growing knowledge of the conditions which are best adapted to yield a satisfactory growth at each stage of the plant's development; efforts to forecast, in fact, help towards that knowledge. Such knowledge makes it possible to place the finger on the critical stages and to take such steps as may be possible to modify the conditions at those stages to the plant's requirement. Further, it makes it possible to reduce the labour of finding the variety of any plant best suited to any particular conditions. But such methods can only be perfected where a sufficient series of accurate and concordant data both of weather conditions and of crop production are available for analysis.

No reference has been made to the large amount of work that has been done on the relation between crops and climate in temperate countries. The problem here is more complicated, humidity is not the only, nor perhaps the most important, climatic factor influencing growth. Temperature is obviously an important factor, and at the same time its effect is by no means easy to interpret owing to the irregular and rapid nature of the fluctuations which renders measurement difficult. Progress in forecasting, therefore, is likely to be most rapid in the tropics and the labour incurred in maintaining a record of climatic and crop data under tropical conditions is assured of an ample reward.

CITRONELLA

DEPARTMENT OF AGRICULTURE, CEYLON,

LEAFLET No. 54.

The trade in citronella oil, which received a set-back in the period 1917-21 appears to be regaining its position of pre-war days. The average annual export for the three periods of 5 years is as follows :—

1912-16	...	1,527,246 lb. ;	average price per lb.	Rs. 0·85
1917-21	...	1,075,909 lb. ;	average price per lb.	Rs. 0·77
1922-26	...	1,300,306 lb. ;	average price per lb.	Rs. 1·55

The average price for the periods has improved considerably, but in the last five years the price has fluctuated much, and shows a tendency to drop.

The following table shows the quantities exported and prices during the past five years :

Year	Quantity exported	Total Value of Exports	Average Price per lb.	Highest Price per lb. reached during the Year
	lb.	Rs.	Rs.	Rs.
1922	1,299,889	1,638,242	1·30	1·60
1923	1,121,271	2,130,283	2·09	2·44
1924	1,433,381	2,941,291	2·03	2·45
1925	1,415,639	2,259,465	1·37	2·00
1926	1,431,351	1,774,326	0·99	1·25

The quantity exported in 1927 amounted to 1,358,191 lb. valued at Rs. 1,264,745.

The countries to which citronella oil is exported are seen from the following table :

PERCENTAGE OF TOTAL ANNUAL EXPORTS

	1922 Per cent.	1923 Per cent.	1924 Per cent.	1925 Per cent.	1926 Per cent.
United States of America ...	58·7	50·5	39·9	44·8	40·2
United Kingdom ...	23·8	34·7	38·0	23·0	29·6
Germany ...	2·1	1·5	4·4	8·2	9·0
Australia ...	6·8	3·7	4·6	6·7	5·0

The area under citronella in Ceylon is 36,378 acres, and the grass is cultivated almost entirely in the Southern Province. The industry is confined mainly to the Matara (22,382 acres) and Hambantota (13,660 acres) Districts.

Citronella thrives in dry regions, on hard gravelly soils which are not retentive of moisture; hence highland and slopes of hills in the Southern Province are all occupied by this crop. At present the cultivation of citronella is restricted to the low-country below an elevation of 1,000 feet. At higher elevations and under moisture conditions growth has been good, but the yield of oil has been low. The average annual rainfall of the citronella district is 70 inches, but the crop is capable of withstanding severe droughts.

The botanical name of citronella is *Cymbopogon nardus,* Rendle of which two types are cultivated:

(*a*) "Maha-pengiri," also known as the old citronella grass, and "Winter's grass sometimes considered a distinct variety and named *C. Winterianus;* and (*b*) *"Lena-batu pengiri"* or briefly *lena-batu,* also known as *heen-pengiri.*

The grass known as "Java maha-pengiri" also appears to be a distinct variety.

"Maha-pengiri" yields a finer oil and a greater output than "Lena-batu pengiri." Java citronella oil commands a higher price than the Ceylon oil.

The first plantation of citronella, at Baddegama, consisted solely of the variety "Maha-pengiri." "Lena-batu" originated subsequently in a plantation in Matara, and in a short time almost entirely replaced the old grass on account of its being so much hardier.

The comparative differences of habit of the two varieties are as follows:

Maha-pengiri		*Lena-batu*
Is a surface feeder, and is liable to be uprooted at the time of cutting	...	Deep-rooted
Requires two weedings before the first cutting	...	Two cuttings can be made before the first weeding
Grows more slowly	...	Faster-growing
Can be cut only twice a year	...	May be cut three or four times a year
Requires a richer soil	...	Grows on poor soil
Not able to stand a long drought	...	Will stand prolonged drought
Requires to be replanted after two years	...	No replanting needed for 10-20 years

PLANTING AND CULTIVATION

Propagation is entirely vegetative by division of the root-stock. These divisions should be planted out in suitable weather, when the rains have set well; otherwise watering to prevent losses would be difficult as well as expensive.

The usual method is to plant groups of 4-5 shoots at distances of 1 foot. As the plants grow up they run together into a large clump, and the clumps are formed about 4 feet apart. There does not appear to be any regularity observed in planting, and a plantation presents the appearance of irregularly scattered clumps. In most instances as many as 40,000 plants may be found to the acre; but better results have been obtained by limiting the number to 15,000. It would be preferable to plant shoots at a distance of 1 foot in rows 3 feet apart. This would facilitate manuring and hoeing between the rows; while the manured space would be available for replanting which it is recommended should be carried out after 5-10 years, when the yield of oil has begun to diminish. Weeding is usually performed at the time of cutting. This should be done at least twice a year. At the same time the bushes should be cleaned by removing all damaged and decayed leaves.

The usual practice of manuring is to use the grass from the stills as a mulch. Sometimes furnace ashes are also applied mixed with the waste grass. Beneficial results have been obtained by adding cattle manure.

The following artificial fertilizer mixture is recommended by the Agricultural Chemist:

Groundnut cake	...	...	150 lb.
Sulphate of ammonia	...	...	50 lb.
Kainit	...	...	100 lb.
Superphosphate	..	...	50 lb.

200-300 lb. of the mixture would be sufficient for an acre.

As citronella is usually cultivated on hillsides which are liable to suffer from soil erosion, the crop should be planted in lines along the contours. Drainage has not been carried out in the old plantations; but it would be beneficial to cut contour drains at distances of 30-40 feet apart.

The cultivation of "Maha-pengiri" or "Winter's grass" differs essentially from that of "Lena-batu," which is the commonly cultivated variety. "Maha-pengiri" is to be found at Baddegama, and is cultivated on ridges in the flat valley land. Three rows of plants are set down a foot apart, on ridges 8 inches high. The ridges are formed 6 feet apart. This variety does not grow as rapidly as "Lena-batu," and requires to be replanted after two years. The intervals of cutting are longer than in the case of the common variety. Usually only two cuttings are obtained in a year.

The oil-content of "Maha-pengiri" is 0·6 per cent. which is nearly 50 per cent. higher than the oil-content of the "Lena-battu" variety.

HARVESTING AND YIELD

If growth has been satisfactory, the first cutting may take place at the end of the sixth month. After this, cuttings can be made every third or fourth month depending on the state of the weather.

The maximum yield is obtained in the third year, and after the fifth year the yields diminish rapidly. In the third year the quantity of grass cut may be 15,000 to 20,000 lb.; and this may yield 60-80 lb. of oil, equivalent to 40-50 "bottles" of 24 oz. At this stage the oil-content of the grass is 0·4 per cent. The average yield for the first three years may be taken as 45 bottles per acre per annum.

From the fourth to the fifteenth year the average annual yield per acre is estimated at 26 bottles or about 39 lb. of oil. The average quantity of grass then cut per acre per annum varies between 3,000 and 10,000 lb.

The yield varies with the season, being highest during the hot weather in March-April, and low during the wet season and the flowering period. The October-November crop is higher in weight, but lower in oil-content owing to the flowering. Cuttings therefore should take place regularly before the flowering stage. After cutting, the grass should be left to wilt for a day; but it should not be heaped as this will induce fermentation and consequent deterioration.

The oil obtained from this partially dry grass is sweeter in fragrance and is of better quality than that obtained from grass distilled immediately after cutting.

DISTILLATION

The method of distillation practised in Ceylon is as follows:

The oil is distilled by means of steam. The boiler is fed with hot water from the condenser tank, and the spent grass is used as fuel. The steam pressure is about 10 lb.; but in some cases is said to be as high as 60 lb.

From the boiler the steam is led into the stills which are usually two in number, from 6-9 feet high, and 3-6 feet in diameter. After the still is tightly filled with grass, the lid is fastened on, and steam let in from the boiler. The tubular prolongation of the funnel on the top of the lid leads to the condensing worm which is kept cool by means of flowing water.

The distillate consists of water and oil, and is collected in a copper tank, 3 feet in diameter and 18 inches deep, with a siphon at the base reaching to about the level of the top. When the tank is nearly full, the siphon begins to discharge the water in the lower level of the tank. The oil which is lighter floats. When a quantity of the oil has been collected it is drawn out and filled in bottles or drums.

CITRONELLA OIL

Pure citronella oil varies in colour which may be pale-yellow, greenish, or reddish-brown.

The purity of the oil is judged according to the following standard:

		Ceylon Oil "Lena-batu" Var.	Java Oil "Maha-pengiri" Var.
Sp. gr.	...	0·898—0·920	0·884—0·900
Opt. rotation	...	−7°— −20°	0°— −3°
Ref. ind. at 20°	...	1·4790—1·4890	1·4650—1·4720
Total "geraniol"	...	55—64%	83—92%

The Ceylon oil has a higher sp. gr. and lower "geraniol" content than the Java oil. The variability in composition of pure samples may be due to the method of distilling and quality of the grass at time of cutting.

The general test applied to citronella oil is "Schimmel's test," which is an empirical one, and depends solely on the solubility of the oil in alcohol. It is as follows: when the oil is shaken with 1-3 vols. of 80 per cent. alcohol, a clean or only faintly opalescent solution should be formed. When the solution is diluted to 10 vols. with 80 per cent. alcohol, no oil drops should separate on standing, though a mere turbidity may be disregarded if previously present.

This test has been found insufficient to detect the addition of petroleum (kerosene) and alcohol (methylated spirit). Some citronella oils do not show a turbidity even if they contain added kerosene to the extent of 5 per cent. To overcome the difficulty of detecting adulteration with kerosene, a test known as "Raised Schimmel's Test" has been adopted, and is carried out as follows: two tests are made side by side; one exactly as usual in the ordinary Schimmel's test; the other after the addition of 5 per cent. Russian petroleum to the oil under examination. Both the original oil and that to which petroleum has been added should be soluble in 80 per cent. alcohol as employed, and oily drops should not separate in either case.

The other method of judging the purity of citronella oil is on the basis of total "geraniol" content.

It has been found by experiments that some citronella oils which pass the raised Schimmel's test when fresh fail to so do after keeping for some length of time. On the whole, "while Schimmel's test is valuable as a rough and ready means of detecting gross adulteration with petroleum, it is of little use where this adulterant is present in small quantities only."

Recently it was found that spirit in some form had been used to a fairly large extent in the adulteration of citronella oil. This has the effect of permitting the addition of a large amount of kerosene. The citronella oil, nevertheless, is still able to pass Schimmel's test. This form of adulteration can however be detected by the lighter specific gravity of the oil.

MEETINGS, CONFERENCES, ETC.

COCONUT RESEARCH SCHEME

BOARD OF MANAGEMENT

MINUTES of the fourth meeting of the Board, held at 2-30 p.m. on Monday, January 20, 1930, in the old Legislative Council Chamber, Colombo.

Present :—Dr. W. Small, M.B.E. (in the chair), the Hon'ble Mr. C. W. Bickmore, C.C.S., Mr. J. Fergusson, the Hon'ble Mr. C. H. Z. Fernando, the Hon'ble Sir H. Marcus Fernando, the Hon'ble Mr. A. Mahadeva, Mr. John A. Perera, J.P., U.P.M., Gate Mudaliyar A. E. Rajapakse, J.P., U.P.M., Mr. J. I. Gnanamuttu, (Secretary).

Apologies for absence were received from Mr. N. R. Outschoorn, Mr. J. Sheridan-Patterson, J.P., U.P.M., and the Hon'ble Mr. D. S. Senanayake.

1. *Minutes.*—The minutes of the meeting held on October 2nd, 1929, copies of which had been circulated to members, were taken as read and were confirmed and signed by the Chairman.

2. *Finance.*—(a) A statement of receipts and expenditure for the quarter ended 31st December, 1929, was passed without comments. An estimate of the income and recurrent expenditure anticipated in 1930, as well as the approximate capital expenditure on acquisition of estate, erection and equipment of laboratories and bungalows, was tabled. It was noted that the sum required out of the loan of Rs. 200,000 provided under the Coconut Research Scheme Ordinance would be about Rs. 69,000. Mr. Bickmore doubted whether the Government grant of Rs. 200,000 could be fully utilized while only a portion of the loan was required for expenditure. Mr. Fernando stated that the matter was considered by the Select Committee which reported on the Ordinance and that the intention had been to allow the grant to be used before any part of the loan was drawn from the Treasurer.

(b) The Chairman read correspondence with the Colonial Auditor relating to the audit of the accounts of the Scheme. Mr. Bickmore was of opinion that so far as the present accounts of the Scheme were concerned, the procedure proposed was satisfactory. It was resolved that the proposed examination of a monthly cash account and supporting vouchers, checking the same with authorities, a two-day half-yearly inspection of accounting and store records and checking of an annual balance sheet, at a cost of between Rs. 200 and Rs. 300 per annum, be accepted as adequate, pending the opening of the research station of the Scheme.

3. *Powers of Board in relation to the Staff.*—The Chairman invited comments upon the view expressed by Mr. E. J. Samarawickrame, K.C., that the Board had powers to pay bonuses or gratuities or to institute a provident fund, and the opinion of the late Attorney-General that similar powers did not exist under the Local Boards Ordinance. Mr. Bickmore stated that an ordinance was about to be introduced which empowered Local Bodies to create provident funds of their own. Sir Marcus Fernando was of opinion that if the new ordinance was likely to be passed in the current year the Board would do well to postpone action. The Chairman undertook to enquire from the Tea Research Institute what proportion of an officer's salary was contributed by that Scheme and what proportion by the officer himself.

4. *Estate Sub-Committee.*—The Chairman reviewed the work carried out by the Sub-Committee which had finally decided to recommend two estates for consideration. Of these the better one was Bandirippuwa Estate, situated within one mile of Lunuwila railway station, and which was exactly suited for the purposes of the Scheme. In reply to Mr. Mahadeva the Chairman added that the estate would be the central station of the Scheme, that sub-stations in various zones of the coconut districts would be required later, that land for new planting was not essential at the central station, and that seed selection, etc., could be carried out at the smaller stations. Bandirippuwa Estate would be largely for the purpose of manurial experiments and a fully planted estate of uniform growth was desirable. He added that the estate would be worked at a profit from the start and it was essential that no more time should be lost in establishing the central station. The Chairman proceeded to say that all the members of the Sub-Committee were in favour of Bandirippuwa Estate, although two of them thought that the price demanded was high. Sir Marcus Fernando moved that the Board do empower the Estate Sub-Committee to treat with Messrs. J. R. & H. A. de Silva & Co. for the purchase of 200 acres of Bandirippuwa Estate at the price of Rs. 1,250 per acre. Mr. John A. Perera seconded, and the motion was carried unanimously.

5. *Staff.*—(a) A précis of the replies from insurance companies relating to a scheme of endowment insurance for the staff of the Scheme was considered. It was decided that the question of an endowment insurance be dropped for the time being, and that the insurance companies be so informed and thanked for the information supplied by them.

(b) An application from the Clerk/Shorthand-Typist for an allowance in lieu of holiday warrants was considered. It was decided that holiday warrants be issued to this officer in the same way as to clerks in Government service and that a commuted payment should not be allowed.

6. *Travelling, Coconut Research Scheme.*—The question of mileage at the rate of 25 cents allowed to outstation members for attendance at meetings of the Board was discussed. It was resolved that the flat rate of 25 cents already sanctioned by the Board should be adhered to.

By Order,

(Sgd.) J. I. GNANAMUTTU,

Secretary,

Coconut Research Scheme.

DEPARTMENTAL NOTES

REVIEW

TROPICAL AGRICULTURE*

CONSIDERABLE development and change has taken place in the field of tropical agriculture within the last three and a half decades, and, as the results of research work in the various parts of the tropics become better known, the scope increases and the field perceptibly widens. A book which purports to deal with tropical agriculture as a single subject without extending to encyclopaedic proportions must of necessity be in the nature of a guide to the sources of more detailed information, and to this end the new and revised edition of the late Sir Henry Alford Nicholls' well-known book supplies a long-felt want in this particular field. By the retention of most of the original text nothing has been lost, and by the addition of illustrations, references, and text material much has been gained. The intention of the author has been well kept in view in the revised form of his text-book, and as a preliminary text-book for agricultural schools and educational institutions throughout the tropics it should prove a most valuable standard work. It is well bound, particularly free from printer's errors, and though containing about double the number of pages is little more than half as thick again as the previous editions. The value of the book as a whole would have been considerably enhanced by the addition to the text of a few pages dealing with dry farming and one of the main cereals of the eastern tropics, namely kurakkan (*Eleusine Coracana*). In the chapter devoted to citrus friuts greater stress might have been laid on the important question of the relationship of stock and scion and to the question of training and careful pruning while the plants are young.

More extended reference than inclusion in a chapter heading could be considered desirable to the plantain (*Musa paradisiaca*) which is still one of the most important food crops of the tropics and produces more food per acre than any other crop. In the sections on spices and essential oils the difference in value between the leaf oil and the bark oil obtained from the cinnamon plant might with advantage have been indicated, the latter fetching on the average as many shillings per ounce as the former fetches per pound. It is curious that for convenience no mention is made in the section on pepper of the valuable form of support for the creepers which is provided by the kapok tree (*Eriodendron anfractuosum*), though it is referred to in the section on fibres which deals with this plant. The section on Para rubber (*Hevea brasiliensis*) is somewhat out of date, especially on the question of tapping and tapping knives, of which the illustrations on pp. 483 and 484 give evidence, while no mention is made except in the list of references to the subject of bud-grafting as applied to this important crop.—W.C.L-S.

* *A Text-book of Tropical Agriculture* by Sir Henry Alford Nicholls, C.M.G., M.D., F.L.S. Revised by John Henry Holland, F.L.S. XXXIII+639 pp., 213 figs. and illustrations. Macmillan & Co., Ltd. 1929. Price 15/-.

ANIMAL DISEASE RETURN FOR THE MONTH ENDED 28th FEBRUARY, 1930.

Province, &c.	Disease	No. of Cases up to Date since Jan. 1st 1930	Fresh Cases	Recoveries	Deaths	Balance Ill	No. Shot
Western	Rinderpest	122	68	20	75	4	23
	Foot-and-mouth disease	82	74	30	...	52	...
	Anthrax	...	...	...	...	...	...
	Piroplasmosis	...	...	...	...	...	...
	Rabies. (Dogs)	...	...	...	...	...	...
Colombo Municipality	Rinderpest	..	...	...	...	...	...
	Foot-and-mouth disease	199	198	75	...	124	...
	Anthrax	...	...	...	...	...	...
	Haemorrhagic septicaemia	2	...	...	2	...	...
	Black Quarter	2	...	...	2	...	...
	Rabies (Dogs)	5	2	...	...	...	5
Cattle Quarantine Station	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	...	..	...	...	...	...
	Anthrax (Goats)	64	16	...	64	...	...
Central	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	398	228	172	2	224	...
	Anthrax	...	...	...	...	...	...
	Rabies (Dogs)	1	...	...	...	...	1
	Haemorrhagic septicaemia	...	...	...	...	...	...
Southern	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	188	152	177	6	5	...
	Anthrax	...	...	...	...	...	...
Northern	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	788	...	787	1	...	...
	Anthrax	...	...	...	...	...	...
Eastern	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	88	15	86	2	...	...
	Anthrax	...	...	...	...	...	...
North-Western	Rinderpest	2140	565	19	1585	5	531
	Foot-and-mouth disease	3	3	3	...	...	..
	Anthrax	...	...	...	...	...	...
	Piroplasmosis						
North-Central	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	1069	506	905	24	140	...
	Anthrax	...	...	...	...	...	...
Uva	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	59	59	...	...	59	...
	Anthrax	...	...	...	...	...	...
	Haemorrhagic septicaemia	...	...	...	...	...	...
Sabaragamuwa	Rinderpest	25	6	5	20	...	...
	Foot-and-mouth disease	861	178	637	3	221	...
	Anthrax	...	...	...	...	...	...
	Haemorrhagic septicaemia	8	..	...	8	...	...

G. V. S. Office,
Colombo, 10th March, 1930.

G. W. STURGESS,
Government Veterinary Surgeon.

METEOROLOGICAL REPORT

FEBRUARY, 1930.

Station	Temperature				Humidity		Amount of Cloud	Rainfall		
	Mean Maximum	Difference from Average	Mean Minimum	Difference from Average	Day	(Night from Minimum)		Amount	No. of Rainy Days	Difference from Average
	°	°	°	°	%	%		Inches		Inches
Colombo	87·6	+0·6	72·3	+1·2	68	90	3·8	1·97	7	— 0·11
Puttalam	88·1	+1·3	70·3	—1·1	68	95	4·0	1·00	4	— 0·28
Mannar	88·1	+1·5	73·7	+0·8	66	90	3·3	0·13	3	— 1·21
Jaffna	85·8	+1·2	72·7	+0·7	68	90	4·3	0·25	2	— 1·05
Trincomalee	83·3	+0·7	76·5	+1·8	74	79	3·4	2·22	3	+ 0·04
Batticaloa	83·8	+0·6	73·6	+0·9	74	90	4·3	0·82	2	— 2·66
Hambantota	87·2	+1·1	73·3	+1·2	68	88	2·5	1·07	4	— 0·35
Galle	85·7	+1·1	73·4	+0·1	73	93	4·8	4·44	4	+ 1·53
Ratnapura	92·4	+3·4	71·4	—0·5	63	93	4·0	5·84	13	+ 1·30
A'pura	86·7	—1·0	70·0	+1·6	69	95	4·5	3·37	6	+ 1·85
Kurunegala	90·0	—0·2	70·2	+1·3	62	90	4·4	4·70	4	+ 3·04
Kandy	86·3	+1·8	68·1	+1·8	63	85	3·9	2·34	5	+ 0·09
Badulla	79·7	+0·7	63·7	+1·6	72	94	4·5	3·19	6	+ 0·26
Diyatalawa	76·3	+2·4	55·1	—1·0	70	88	4·4	2·06	10	— 0·27
Hakgala	73·3	+2·4	50·9	+1·3	77	90	3·8	3·79	7	+ 0·49
N'Eliya	70·5	+1·1	43·6	—0·6	64	93	4·6	1·37	4	— 0·66

The rainfall of February was within a couple of inches of its average throughout three quarters of the Island. Stations where the average was passed by more than this amount were chiefly in Sabaragamuwa, the Southern Province, southern Uva, and inland parts of the N.W.P. Deficits of more than 2 in. occurred chiefly, but not exclusively, in the Eastern Province. Most of the rain fell in the first half of the month.

The highest total for the month was at Keragala, 13·41 inches, while other stations with over twelve inches were Alutnuwara and Mawarella (S.P.). Falls of over 5 inches in a day were recorded at Alutnuwara, Beau Séjour, Buttala and Hali Ela on the 8th and at Unichchai on the 14th.

It will be seen in the table that temperatures were on the whole decidedly above average. February temperatures are one of the items (though by no means the most important one) that have shown some correlation with the amount of rainfall in the subsequent monsoon, and in this case point to monsoonal rainfall being above rather than below average.

Wind velocities were about normal. Figures for amount of cloud were on the whole below average, while those for duration of sunshine were decidedly above. Thus at Colombo and Batticaloa the mean numbers of hours of bright sunshine were 9·9 and 9·7 respectively, which in both cases were more than an hour per day above the average.

A. J. BAMFORD,
Supdt., Observatory.

NOTE ON METEOROLOGICAL REPORT

The table in this month's Meteorological Report includes several new features. The most obvious is that instead of giving only the mean temperature of the air and its departure from average, the mean daily maximum and mean daily minimum are now shown separately. The minimum temperature on the surface of the ground is usually a little below the minimum air temperature, which is taken at a height of about four feet above the surface.

An important innovation that may require some explanation is in the humidity. The relative humidity is usually indicated by expressing the amount of water vapour actually present in the air as a percentage of the amount that would give saturation under the other conditions that exist at the time. The method of measuring the humidity is by comparing the temperature of an ordinary dry thermometer with that of one whose bulb is artificially wetted. A low humidity corresponds to a dry atmosphere, in which evaporation takes place rapidly from the wet thermometer, which consequently records a temperature considerably below that of the ordinary dry one. In Ceylon the humidity is usually very much greater at night than by day, and a single mean value is thus an inadequate description of conditions through the 24 hours. In future two columns will be devoted to this item. The first shows the mean of the values at 9-30 a.m. and 3-30 p.m. and gives a fair idea of the conditions by day. The second gives the value as determined from the minimum dry and minimum wet thermometers. It is obvious that this determination will not be perfectly correct, unless the two thermometers reach their minimum values simultaneously. This condition is not always fulfilled, and hence the night values are not so precise as those taken by day. However, the very considerable difference between day and night conditions, and the fact that the humidity does not vary very much through the night, makes it desirable to give a separate estimate of the latter, even though it is admittedly only an approximate one.

In the column dealing with Cloud, the amount of clouded sky is given on the scale 0-10 where 0 denotes an absolutely clear sky and 10 a completely overcast one.

No change has been made in the columns giving the amount and frequency of rain, and the variation of the former from average.

The columns reporting wind will in future be omitted to make room for the new columns referred to above, but reference to abnormalities in the distribution of wind will be made in the letter press below.

Reference to the number of hours of bright sunshine at a few stations will also be made in future, either as figures in a column of the table, or in the letter press beneath.